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FINAL REPORT

MAY 15, 1971

# AN ECONOMIC MODEL SYSTEM FOR THE ASSESSMENT OF EFFECTS OF AIR POLLUTION ABATEMENT

## DEVELOPMENT AND DEMONSTRATION PHASE

*Prepared for:*

OFFICE OF AIR PROGRAMS
ENVIRONMENTAL PROTECTION AGENCY

by
CONSAD Research Corporation

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16. Abstracts

The report presents a summary of the development, demonstration, and assessment of an economic model as an operational, analytical tool for abatement policy assessment. This economic model which was initiated as part of the Regional Air Pollution Analysis Program focused on the regional economies of the various Air Quality Control Regions. Thus it will be useful for assessment of control strategies at the regional level, where most of the implementation plans are prepared. There has been an increased focus in the model system toward the assessment of interregional and national economic effects. However, this system is still a regional economic system with limited capabilities to measure the interregional and national effects.

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FINAL REPORT

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# PREFACE

To economists, optimal resource allocation decisions require knowledge of the costs, effects and benefits of alternatives. Because the real world is complex, models or simulations are used in economic analysis to test the outcome of alternatives strategies.

This study by the Office of Air Programs and CONSAD Research Corporation represents the first systematic effort to determine the indirect economic effects of air pollution control costs and to test the possible results and implications of some alternative approaches to the sharing of costs of control among producers, consumers and the public generally.

Because it is a new modeling effort and the data inputs somewhat old, the results must not yet be considered anything but illustrative of the potential capability of economic modeling on such a wide scale. The present exercise utilizes engineering estimates of costs of control and makes specific assumptions regarding the level of benefits attainable from air pollution control and the manner in which those benefits are introduced to and experienced by the system.

It will quickly be obvious to the careful reader that better control cost estimates are needed together with a more flexible method of introducing benefits if the model is to come closer to describing reality. The model obviously requires new information on the facts of economic life and of the control requirements, technology and costs implicit in the Clean Air Act Amendments of 1970.

It will be for the users and future developers of the model to supply the necessary improvements needed in order to make it a usable contributor to policy analysis and formulation. Despite its limits, however, we believe that this economic modeling effort represents a most important first step and that it should be viewed at in that light.

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Chief Economist
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Office of Air Programs

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Any opinions expressed in this report are those of CONSAD and do not necessarily reflect the views of the individuals cited above.

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*Formerly Air Pollution Control Office

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# EXECUTIVE SUMMARY

## 1. INTRODUCTION

In sustaining rapid population growth, high levels of consumption, technological innovation, and a quickening pace in the use of resources, Americans have been hard on their environment -- the vegetation, land, air, and water that sustain the biotic and industrial processes. As a result, clean air and clean water have become scarce resources.

Pure or relatively unpolluted air is no longer a free good in our society; money outlays must be made to go where air is relatively cleaner or to trap pollutants before they escape into the air. In the past, those who were responsible for pollution did not bear the external costs they generated to the entire society.

With the recent enactment of the Clean Air Act of 1967 and Amendments of 1970, business and industry are now being required to control the amount of pollutants that they discharge into the air. To industry, this requirement means that the production costs for the same amount of output produced prior to the legislation will be increased in proportion to the required investment in air pollution control equipment. Thus, certain industries and regions that have in the past enjoyed the economic advantage of low-cost production may face some degree of economic decline due to the requirements of pollution abatement.

There would be, however, offsetting economic effects from air quality control strategies in such regions in at least two ways. First, there would be increased demand for the products of the industries that produce pollution control equipment and low pollutant fuels leading to increased output, employment, and income in those sectors. Second, a variety of general economic benefits result from pollution abatement. Some of those gains are increased labor productivity, and property values, reduced health expenditures, reduced outlays on physical maintenance of homes and plants, and savings in agricultural production activities. These gains would lead to increased consumption, output, employment and income, and would begin to offset the economic reductions resulting from the pollution control costs.

Consequently, air pollution abatement leads to changes in economic output, labor markets, the availability of capital, as well as redistributions within the entire economy. Further, the implementation of air quality programs would have a variety of other effects, such as tax base impacts on communities or variations in land-use and industrialization in various regions.

The Air Pollution Control Office (APCO) of the Environmental Protection Agency (EPA) commissioned CONSAD Research Corporation, under subcontract to TRW Systems, Inc., for the development and demonstration of such an economic model as an operational analytical tool for abatement policy assessment. This economic model initiated in 1968 as part of the Regional Air Pollution Analysis (RAPA) program focused on the regional economies of the various Air Quality Control Regions (AQCRs). As such, it will be useful for assessment of control strategies at the regional level, where most of the implementation plans are prepared. However, there is an increasing interest in air pollution control policy decisions in the last three years at the Federal government level. Therefore, there has been correspondingly an increased focus in the model system described here toward the assessment of interregional and national economic effects in addition to regional effects. However, the model system developed by CONSAD is still a regional economic system with capabilities to measure, in a limited manner, the interregional and national effects. It is called the APCO Regional Economic Model System and has been demonstrated to some degree as an operational tool for control strategy assessment.

## 2. THE APCO REGIONAL MODEL SYSTEM AND THE RAPA PROGRAM

The APCO Regional Model System was conceived as part of the RAPA program in July 1968. To accomplish the task of developing timely abatement strategies requires an extensive examination of the factors involved in the air pollution system, such as meteorology, air pollution control technology, air pollution growth trends, source emission inventories, existing regional air quality conditions, and regional economic impact. Figure 1 outlines the RAPA process and the role of the APCO Economic Model System there.

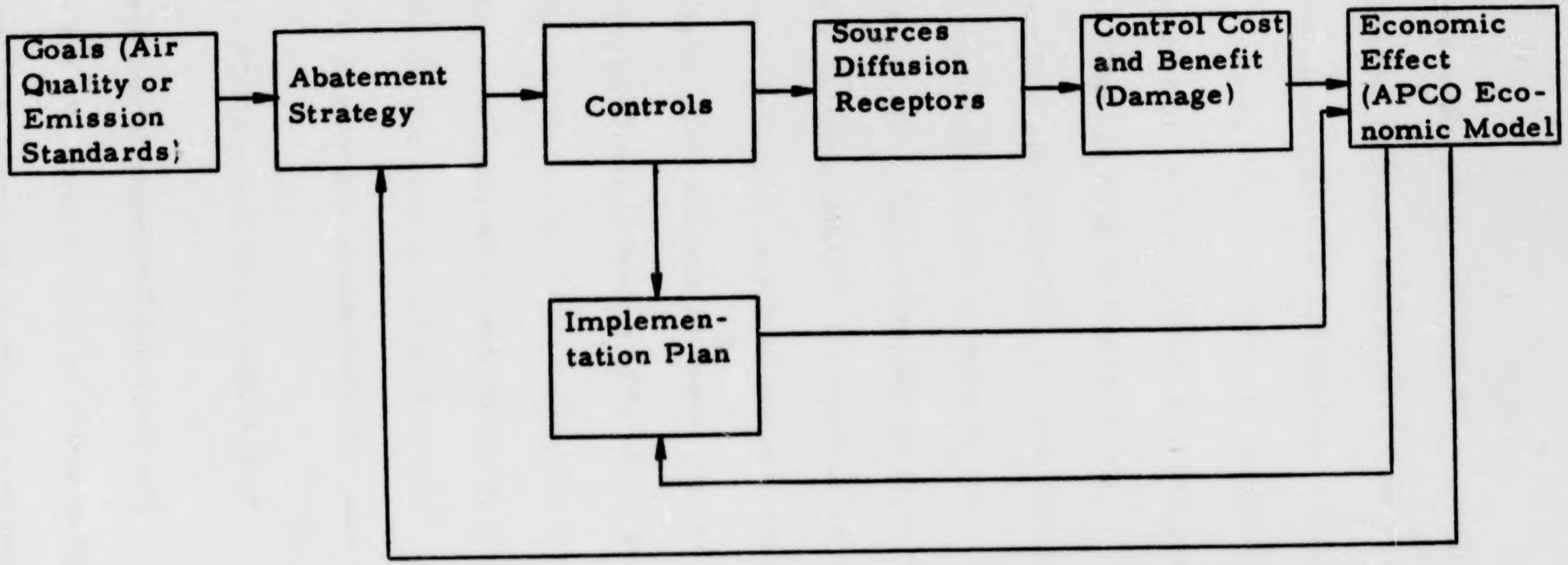
In the first year (Phase I), CONSAD developed a Regional Econometric Model of the St. Louis region where the RAPA was explored first in depth. This model describes the growth patterns of key economic sectors (both high emission and other industries) and estimates the regional product, employment, capital stock and investment change, and value-added by industry, tax receipts and regional unemployment. These estimates are sensitive to a variety of air pollution control strategies. In fact, the economic effects of five hypothetical air quality control strategies were simulated and interpreted, using the model for the St. Louis region.

The second year (Phase II) witnessed an extension of the model to 31 large metropolitan areas. These large urban areas have a varied industrial structure highly representative of the national industrial composition and comprise a significant segment of national output. The structure and outputs of this model are very similar to those of the St. Louis model.

In the current year (Phase III), this model system has been extended in two directions. First, the economic model was extended to

FIGURE 1

REGIONAL AIR POLLUTION ANALYSIS PROCESS


Goals (Air Quality or Emission Standards)
Abatement Strategy
Controls
Sources Diffusion Receptors
Control Cost and Benefit (Damage)
Economic Effect (APCO Economic Model
Implementation Plan

embrace 100 AQCRs, at the same time providing a broader range of economic effects than has been possible so far. Second, the Phase III model provides the capabilities of capturing the economic effects of abatement strategies in one region on all other regions and the structure changes taking place in the national economy.

The Regional Model System as currently developed in Phase III thus covers a significant portion of the AQCRs in the nation and treats them all as a set of interrelated regions. It is a large, complex model which is an operational tool. Its workability has been demonstrated as shown in Figure 2. Three strategies specified by the APCO staff and relating to the incidence of control costs (on the high emission industries, consumer or government), associated with the air quality standards of the 1970 Report to the Congress under Section 305(a) of the Clean Air Act of 1967, were fed into the economic model and the simulation program run to develop the economic effects.

The rest of this report will provide a brief summary of the development, demonstration, and assessment of the regional model system.

## 3. THE MODEL SYSTEM: AN OUTLINE

The Regional Economic Model System has been developed as described above in three phases. At the end of Phase II, the regional model was structured as though AQCRs were economically independent

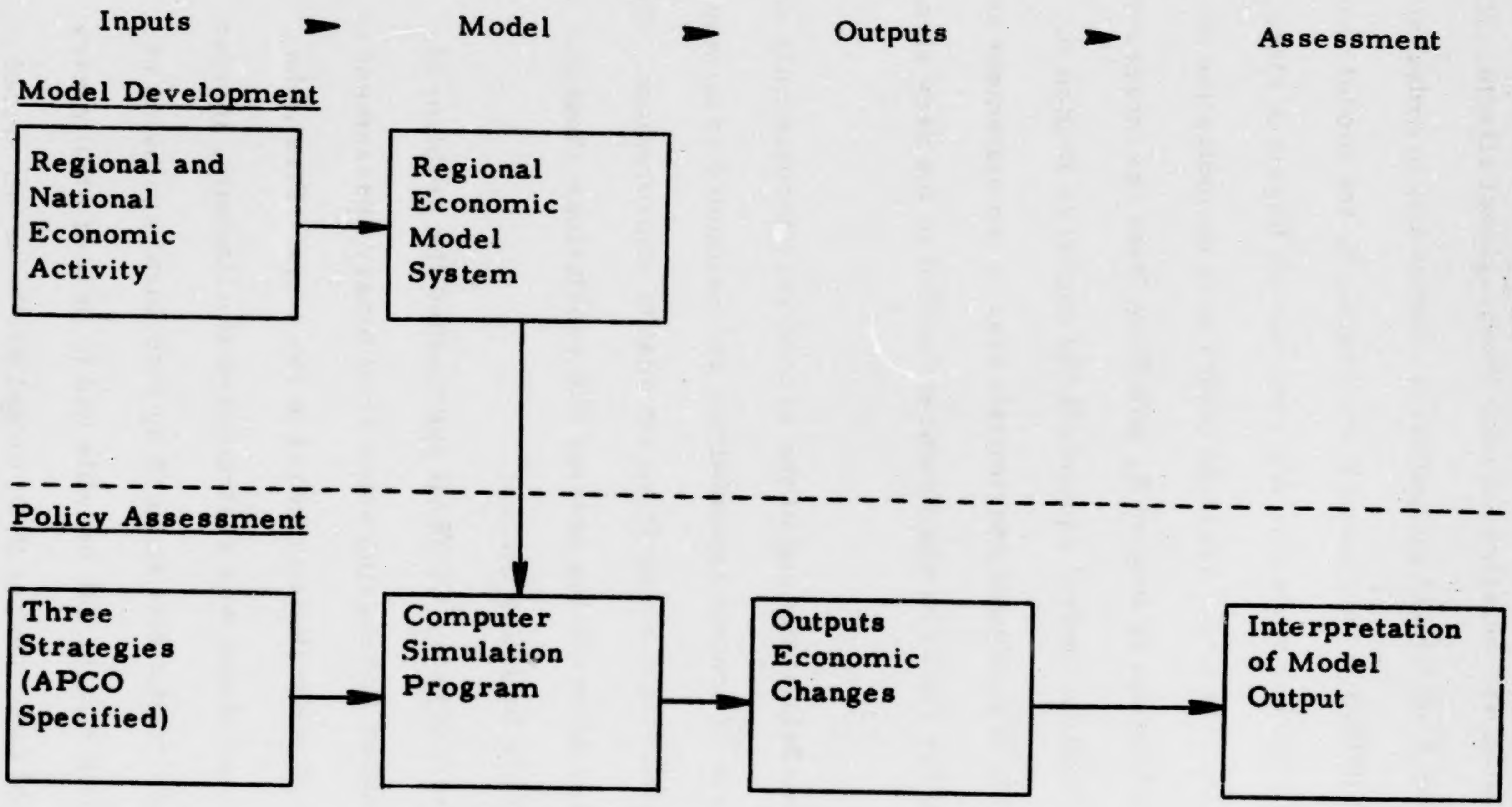

Inputs
Model
Outputs
Assessment
Model Development
Regional and National Economic Activity
Regional Economic Model System
Policy Assessment
Three Strategies (APCO Specified)
Computer Simulation Program
Outputs Economic Changes
Interpretation of Model Output

FIGURE 2

THE APCO REGIONAL ECONOMIC MODEL SYSTEM:
DEMONSTRATION AND USE

of one another. There was no allowance for interregional effects. If, for example, Region A instituted air pollution control and in order to do so imported air pollution equipment from Region B, the model simulated the economic impact of Region A's program on Region A alone, and not on Region B. Thus, the regional model gave no indication of the increase in employment in Region B, resulting from the increased production of air pollution control equipment for export to Region A. There was, however, a source of pessimistic bias in the statement of economic effects of air pollution abatement embedded in the very structure of the model.

Second, the models at the end of the second year focused only on the economic impacts of control expenditures and accounted in no way for any benefits which might result from air quality improvement. This again tended to cause unjustifiably pessimistic conclusions about the economic effects of air pollution control.

During the current year, CONSAD approached the problem of eliminating these biases and making some preliminary assessment of the national impact of air pollution control in two ways. First, the cross-section Regional Model was restructured to eliminate, insofar as possible, the pessimistic bias induced by structural exclusion of interregional feedback effects and benefits and to permit preliminary estimates, a national Input-Output (I-O) model has been introduced to capture (a) a preliminary estimate of structural changes in the national economy, and (b) an interregional feedback scheme to the AQCRs.

Second, the feasibility and desirability of an expressly national model to be interconnected with the current regional model was investigated in considerable detail.

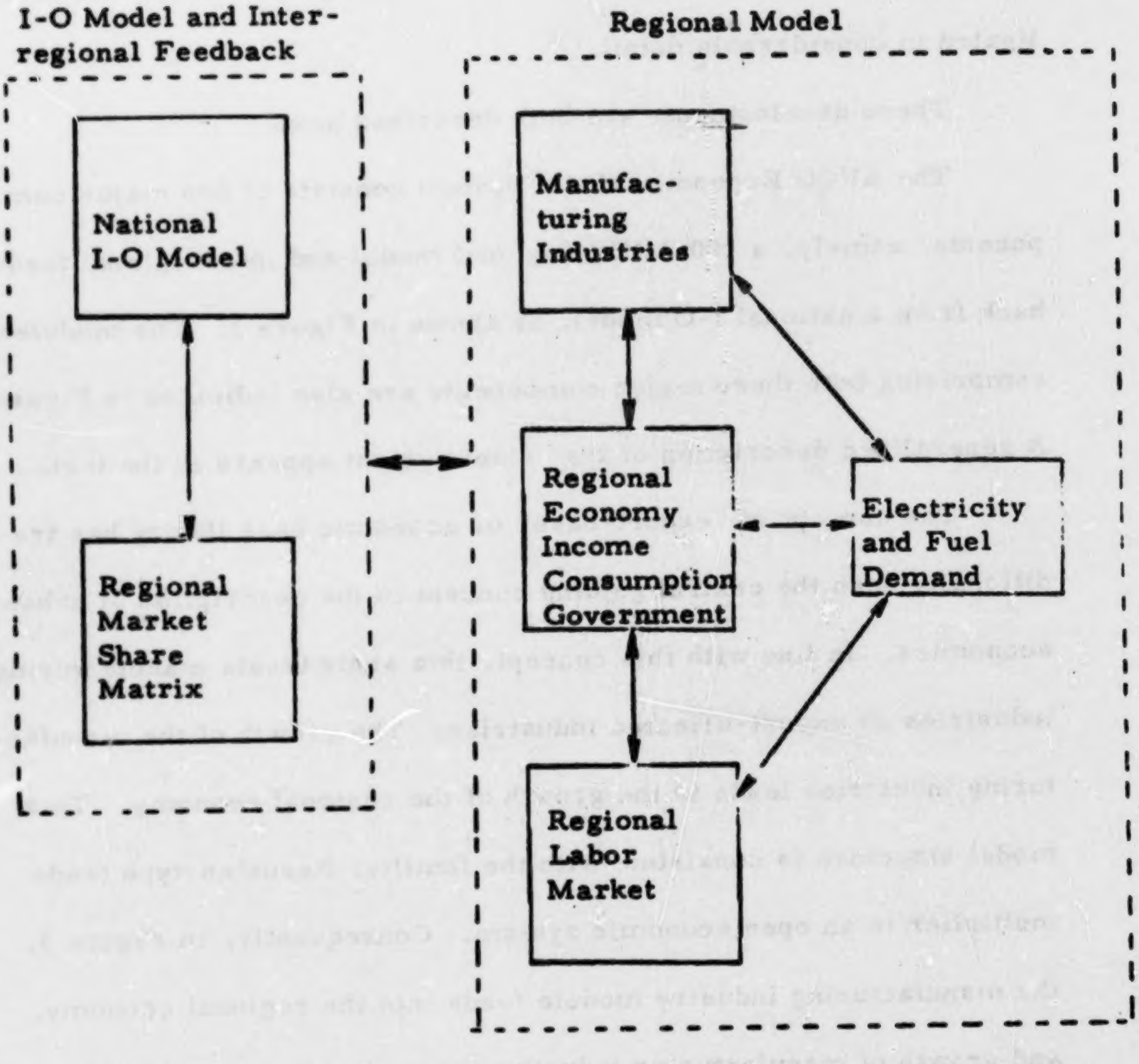
These developments are both described next.

The APCO Economic Model System consists of two major components, namely, a 100 AQCR regional model and interregional feedback from a national I-O model, as shown in Figure 3. The modules comprising both these major components are also indicated in Figure 3. A generalized description of the model system appears in the text.

The concept of "export-base" or economic base theory has traditionally been the central guiding concept in the description of urban economies. In line with this concept, this study treats manufacturing industries as export-oriented industries. The growth of the manufacturing industries leads to the growth of the regional economy. This model structure is consistent with the familiar Keynsian-type trade multiplier in an open economic system. Consequently, in Figure 3, the manufacturing industry module feeds into the regional economy, and growth of manufacturing industry and regional economy determine the regional employment in the regional labor market. By the same token, production and consumption activities are related to the demand

FIGURE 3

MAJOR COMPONENTS OF THE MODEL


I-O Model and Inter-regional Feedback
Regional Model
National I-O Model
Regional Market Share Matrix
Manufacturing Industries
Regional Economy Income Consumption Government
Electricity and Fuel Demand
Regional Labor Market

for electric power and fuels. All these relationships have been formulated into a mathematical model.

In the manufacturing module, the production relations of the manufacturing industry are presented. Output is related to the production factors: labor and capital. Gross profit is given as residual between value-added and wage bill. Investment behavior is related to the profit and capital stock from the previous period. With new investment expenditures and adjustment of depreciation, capital stock of present capacity is determined. Finally, employment in manufacturing sectors is derived from the level of production and wage level.

In the regional economy module, regional income is determined by the level of manufacturing production, regional consumption expenditures and local government expenditures. On the other hand, regional consumption is related to the regional income, and government expenditures are related to the government revenues.

In the regional labor market module, employment by industry, other than manufacturing industry, is derived from the income generated from non-manufacturing sectors. Regional employment, which is the summation of employment from manufacturing and non-manufacturing industries, and unemployment rate, determines the regional labor force in each AQCR.

Finally, electricity and fuel demand modules provide the demand of electricity and fuel derived from production and consumption activity of the region. A substitutional relationship between different types of fuel is also included.

A national I-O system is introduced to serve the role of external market for the regional economy described in the regional model, and also, hopefully, to measure the structural change of the national economy attendant upon air pollution control in the 100 AQCRs.

A more detailed look at the regional model which comprises 162 equations is provided in the text.

As a part of Phase III of the RAPA project, CONSAD also investigated the possibilities and potentials of adding another model to the Regional Economic Model System for the express purpose of assessing the national economic effects of air pollution control. CONSAD planned the use of the Office of Business Economics (OBE) Quarterly Econometric Model to make preliminary estimates of national economic effects. An intensive study of the structure of the OBE model, however, revealed a number of structural properties which rendered it not an entirely desirable tool for national effects assessment.

## 4. TRIAL SIMULATION OF THE MODEL SYSTEM

A computer simulation program of the APCO Economic Model System was developed and a user's guide was provided in Volume II of this report. The Regional Model System, utilizing this simulation program, can trace the effects of a variety of policy tools such as standards or incentives available to APCO, provided the latter are converted into inputs constant with the model logic.

APCO specified three alternative strategies to be tested with the APCO Economic Model System as their basis the control costs envisioned in the 1970 Report to the Congress as required by Section 305(a) of the Clean Air Act of 1967. In this report, cost estimates were made of controlling the emissions of selected pollutants within 100 AQCRs during the period fiscal years 1970 through 1975. The costs reflect the emission reductions of particulates, sulfur oxides, hydrocarbons and carbon monoxides in these 100 AQCRs by 1975.*

---

*Fogel, M. E., _et al._, _Comprehensive Economic Cost Study of Air Pollution Control Costs for Selected Industries and Selected Regions_, Research Triangle Institute. February, 1970, Chapter 4.

| Pollutant | Source Category | Emission Decrease (%) |
|---|---|---|
| Particulates | Solid waste | 77.8 |
| | Stationary combustion | 91.7 |
| | Industrial process | 86.1 |
| Sulfur oxides | Stationary combustion | 52.2 |
| | Industrial process | 36.2 |
| Hydrocarbon | Solid waste | 69.4 |
| | Industrial process | 57.8 |
| Carbon monoxide | Solid waste | 84.7 |
| | Industrial process | 90.2 |

The simulation runs interpreted in this report reflect differing control strategies with respect to the incidence of control cost expenditures -- that is, with respect to who finally pays the cost of controlling air pollution. In Strategy 1, high emission industries pay. In Strategy 2, they are able to pass part of the cost on to consumers as a price increase. In Strategy 3, the government subsidizes 50 percent of the burden the industry picks up in Strategy 2. In all three strategies, electric utilities are assumed to be able to pass on the control costs in the form of price increase to the users

Table 1 presents the sample summary table for one AQCR under the "Industry Pays" strategy. First, a key economic indicator, change in unemployment rate, is analyzed in various AQCRs. This shows that there is a considerable difference between the three alternatives in terms of incidence of adverse effects. The geographic distribution of

## TABLE 1
## SAMPLE OUTPUT OF AN AQCR: A SUMMARY TABLE

| | Without Control | Net Change | Percent Change |
|---|---|---|---|
| MANUFACTURING INDUSTRIES | | | |
| Profit (millions) | 5738.902 | -33.051 | -0.57591 |
| Investment (millions) | 452.000 | -20.394 | -4.51190 |
| Value Added (millions) | 13836.699 | 5.273 | -0.09929 |
| Capital Stock (millions) | 10884.758 | -19.132 | -0.56227 |
| OTHER INDUSTRIES | | | |
| Employment (1000 S) | 3979.71 | - 2.866 | -0.07202 |
| Regional Consumption (millions) | 32445.000 | -30.164 | -0.09297 |
| Total Personal Income for the Region (millions) | 53712.000 | -41.488 | -0.07724 |
| Total Regional Employment (1000 S) | 5123.711 | - 9.293 | -0.18137 |
| Regional Unemployment (percent) | 4.000 | 0.1741 | 4.35349 |
| Total Labor Force (1000 S) | 5337.199 | - 9.660 | -0.18100 |
| Government Expenditure for the Region (millions) | 5944.000 | - 3.929 | -0.06610 |
| Government Revenue from the Region (millions) | 6416.000 | - 4.165 | -0.06491 |
| ELECTRIC POWER DEMAND | | | |
| Total Electric Consumption for the Region (1000 KWS) | 4878.000 | - 6.364 | -0.13047 |
| Electricity Used by Manufacturing Industries (1000 KWH) | 518.000 | - 2.736 | -0.52817 |
| Electricity Used by Other Industries (1000 KWH) | 3205.000 | - 2.205 | -0.06881 |
| Residential Consumption in the Region (1000 KWH) | 1155.000 | - 1.423 | -0.12322 |

all 91 AQCRs show that most of the AQCRs seriously (adversely) affected are located in the highly industrialized north-central (Michigan, Ohio, Indiana, Illinois) and central-east (Pennsylvania, West Virginia) states. AQCRs located in the west and south, in general, do not seem to be affected by air pollution control and some are even better off. The following table shows that adversely affected regions improve from Strategies 1 to 3.

| Categories of Change of Unemployment Rate (%) in AQCRs | AQCRs Included (%) | | |
|---|---|---|---|
| | Strategy 1 | Strategy 2 | Strategy 3 |
| 1. Better off (increase in employment) | 5.5% | 7.7% | 9.9% |
| 2. Negligible (0.01% to 1.00%) | 67.0% | 69.2% | 83.5% |
| 3. Moderate (1.01% to 2.0%) | 19.8% | 19.8% | 3.3% |
| 4. Serious (2.01% and over) | 7.7% | 3.3% | 3.3% |
| Total | 100.0% | 100.0% | 100.0% |

When two other economic indicators -- profits of manufacturing industry and regional personal income -- are also analyzed. The patterns of economic change among AQCRs are similar to that of unemployment. However, if one observes the total effects of 91 AQCRs under the three strategies, the pattern is entirely different.

The view of cost sharing which emerges when results for individual regions are considered is thus quite different from that which emerges from solely aggregative considerations. While cost sharing results in overall worsened economic performance, the number of regions severely affected adversely by air pollution control is reduced. There appears to be a policy trade-off to be made. The policy-maker must decide whether he wishes to affect a few regions adversely to a considerable degree while maintaining good overall economic performance, or slightly reduce overall performance so that a few regions may be spared severe hardship. It should be remembered that the results are preliminary and presuppose a particular cost sharing scheme. It is not the only one which could be undertaken.

These results on differential regional impact are suggestive in many veins, but one in particular deserves comment. Some regions evidently have an economic capacity to meet more rigorous emission and air quality standards than do others.

Some caveats on the structure, data inputs, and use of the model system are in order at this stage. Structurally, the APCO Model System is a cross-sectional regional model; consequently, its strength lies in its assessment of geographical patterns of change in the AQCRs. Its estimates of aggregate changes are less reliable. Second, the 91 AQCRs used in the model covers the greater portion of the economic activity in the nation, but not all. Finally, the model system does not capture the dynamic effects and macro-effects that only a national model can handle. Consequently, the interpretation presented below must be viewed with a dose of caution.

The data inputs used in demonstrating the model have limitations that must be considered. First, the two billion dollar estimate of total annual benefits from control was selected primarily because it was just large enough to offset the direct costs of control and not as an accurate reflection of the actual value of damages reduced. In this sense, the value of benefits may be considered quite conservative. Second, the control cost estimates for each AQCR were drawn from the 1970 Cost of Clean Air Report to the Congress. As such, the control cost estimates related to implementation of previous legislation and involved a number of assumptions regarding availability and price of various control technologies. Furthermore, the price elasticity of demand for the products of high emission industries that were applied in testing strategy alternatives 2 and 3 were based heavily on qualitative information as distinguished from detailed product demand studies.

In conclusion, it must be observed that the trial simulation of three strategies and the interpretation of results has demonstrated to a limited degree the operational nature and strategy assessment potential of the model system. Surely, what has been done here is but scratching the surface of the utilization potential of the model system. What has been done, however, clearly points to the view of the regional economy and environmental system (quality levels) as interrelated systems, and that control activities affect profoundly, in many dimensions, economic activity. However, these economy-environment relationships are more complex than evident in this demonstration. This suggests the need for further efforts in model utilization, sensitivity testing, and model system refinement as appropriate. In such an effort of further utilization of the model system, it is hoped that the possible extension of the model to other media -- water and solid waste -- will receive consideration.

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# 1.0 AIR POLLUTION AND THE ECONOMY: AN OVERVIEW

## 1.1 The Context

The recent upsurge of public concern over environmental questions reflects a recognition that man has been too cavalier in his relations with nature. This concern has manifested itself in a spate of legislation in the last few years on abatement of air, water, noise, and other kinds of pollution.

In the field of air pollution in the last few years, two parallel trends are discernible. On the one hand, the Federal administration has proposed and Congress has passed a Clean Air Act of 1967 and Amendments to Clean Air Act of 1970. This legislation and administrative activity is evidence of the increasing public pressures for cleaner air. On the other hand, concerns about dire consequences of such actions are repeatedly and increasing frequently expressed by business and community.

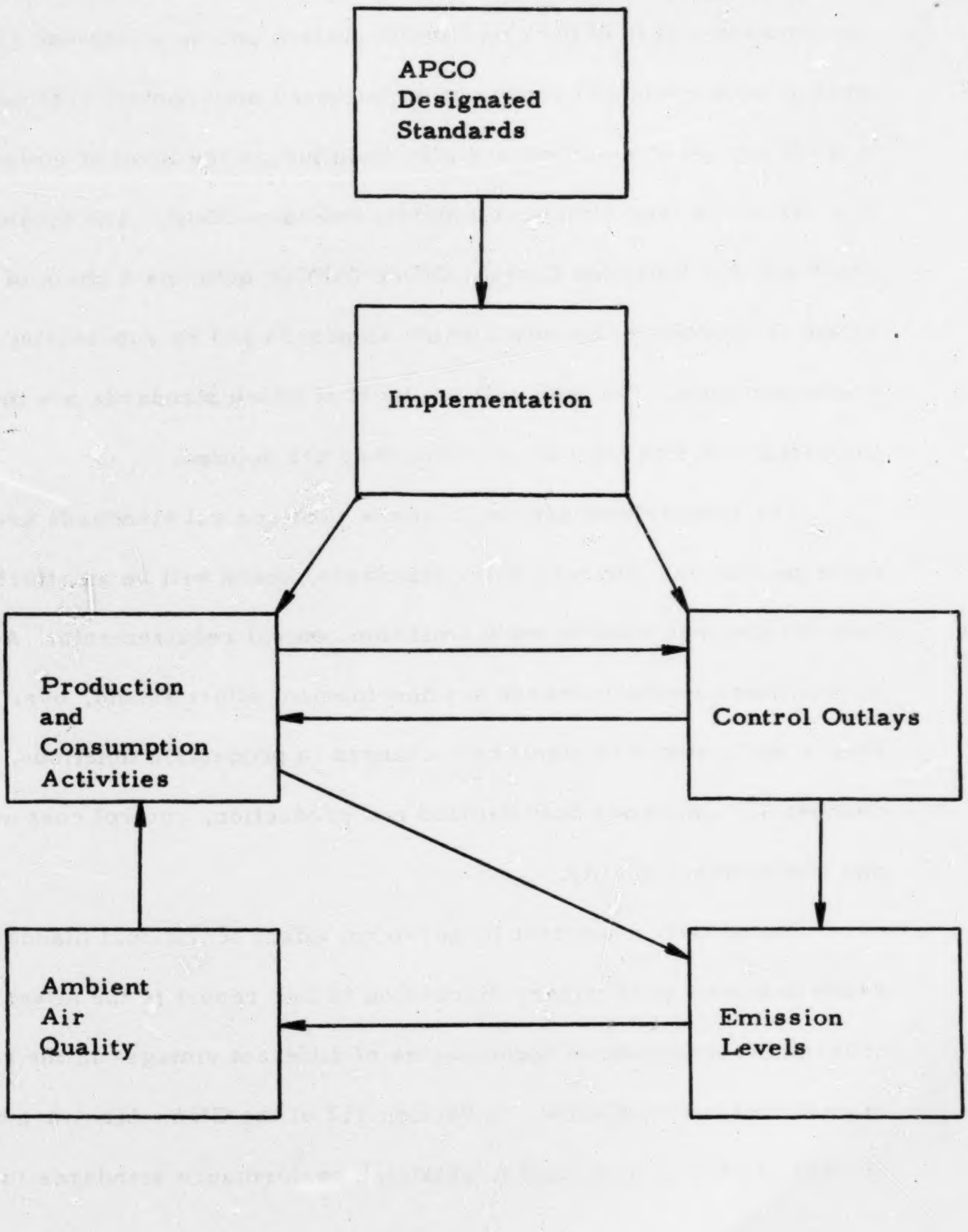
The fears of industry in terms of adverse economic consequences, though expressed often extravagantly, are not baseless. Cleaner air is not free and high emission industries or regions incur costs that affect their output and profits and the regions in which they are located adversely.

In this regard, it may be useful to explore the complex chain of interrelationships between economic activity and various abatement policies such as setting emission standards or achieving the standards through incentives and government expenditures on research and development.

The short-term (0-5 years) chain of events following the promulgation of emission standards is fairly clear in form if not in magnitude. Imposition of standards will result in investment in control equipment, in process changes, and in outlays for non-capital inputs (e.g., low sulfur fuel, maintenance) used in air pollution control. As a result of these outlays, emission and ambient air concentrations will be reduced. Finally, production and consumption activities sensitive to ambient air concentration of pollutants will change. This chain of interdependent events is represented in Figure 1.1.

Figure 1.1 highlights the interdependence between the environment and the economy. Control outlays directly influence production of air pollution control inputs. In addition, implementation plans may directly change production and consumption patterns, as for example, do local plans prohibiting the sale of non-returnable containers or phosphate detergents. Indirectly, control outlays influence production and consumption in two ways: (1) by shifting aggregate supply schedule effecting increasing control costs at all levels of output, and (2) by

FIGURE 1.1
SHORT-TERM EFFECTS OF STANDARDS


APCO Designated Standards
Implementation
Production and Consumption Activities
Control Outlays
Ambient Air Quality
Emission Levels

changing air quality which will shift both aggregate supply and aggregate demand schedules. Moreover, these changes in production and consumption will feed back on control outlays and on emissions since level of production and consumption influence both control cost needed to meet any given standard and also to influence the level of emissions. The system is thus almost completely interdependent. The medium by which the Air Pollution Control Office (APCO) actuates a chain of events within the system is by establishing standards and by supervising their implementation. Not only will the level at which standards are met be important but also the rate at which they are applied.

The longer-term effects (5 years +) of control standards are even more pervasive. Spurred on by standards, there will be an effort to look for cheaper ways to meet emission control requirements. An accelerated private research act development effort should, over the longer haul, result in significant changes in production functions, which changes will influence both demand and production, control cost outlays, and environment quality.

One greatly important longer-term effect of National Standards which deserves preliminary discussion in this report is the effect of differential treatment of technologies of different vintages in the setting of performance standards. In Section 112 of the Clean Air Amendments of 1970, APCO is mandated to establish performance standards for new sources that "contribute significantly to air pollution which causes or contributes to the endangerment of public health or welfare." APCO is not limited in establishing such standards to pollutants for which criteria and control technology documents have been published. It may thus happen that older sources of some pollutants will go uncontrolled, while their newer counterparts will be subject to control standards. It may also happen that controls required of new sources will be costlier than those required of existing sources by state and local governments. The net result will be to make new plants and equipment more expensive relative to existing plants and equipment, and, therefore, to retard investment in new plants and equipment. Since new investment in the manner in which new, more productive, technology frequently comes in line, national economic growth could be slowed.

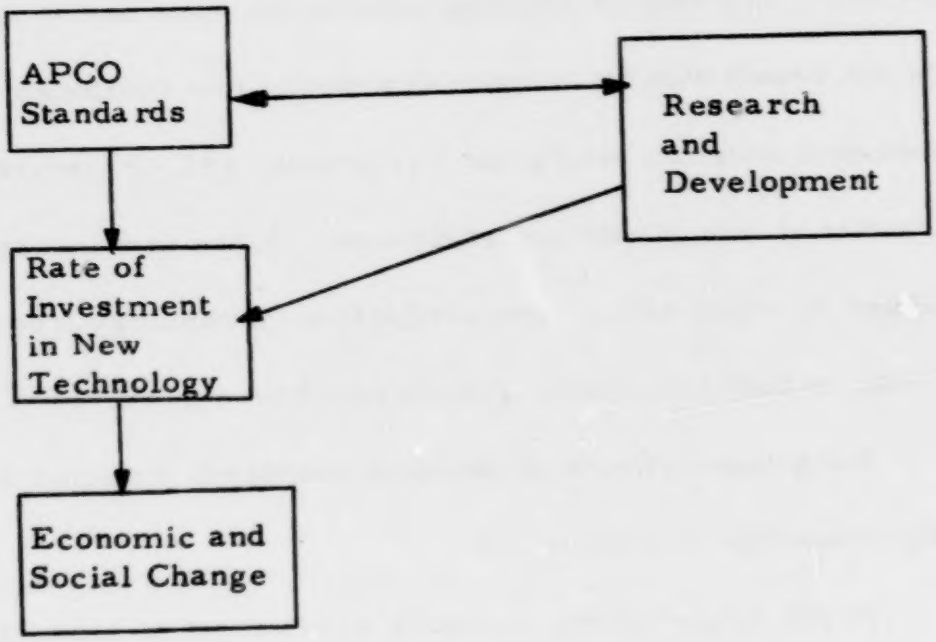
Long-term effects of National Standards Policies are schematically presented in Figure 1.2.

In the longer term, virtually every facet of modern life may be influenced, to a greater or lesser extent, by the character of standards adopted.

The use of Incentive Policies to implement standards differ from other implementation methods (coercion and moral evasion) in that it attempts to use the economic mechanism itself to solve the pollution problem. Incentive Policies are, therefore, intimately related to

FIGURE 1.2

LONG-TERM EFFECTS OF STANDARDS


APCO Standards
Research and Development
Rate of Investment in New Technology
Economic and Social Change

economic policies since Incentives will be effected either through taxation or expenditures. In either event, there will be a marked effect on government finance.

As a part of stepped-up air pollution control activity, all levels of government will be increasing their expenditures for air pollution control. Some of this increased expenditure will be directly for control of emissions from governmental facilities. The majority, however, will be expended in administering air pollution control programs. What effect such expenditures will have on the economy depends primarily on how they are financed. If air pollution control agency expenditures are financed at the expense of other governmental expenditures, the net effect is likely to be small or non-existent.* If, however, air pollution control agency expenditures are additional expenditures, over and above what would otherwise be undertaken, they would have a multiplier effect on Gross National Product (GNP).

In summary, it appears that there are wide and far-reaching economic consequences of abatement strategies expressed in whatever form -- standards, incentives, research and development, and so forth.

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*No reason to think multiplier associated with APC expenditures is any different from that associated with other governmental expenditures.

Indeed, there are signs in the Clean Air Amendments of 1970 itself and in the companion water pollution control legislation that the President and the Congress are already beginning to worry about adverse economic consequences. Particularly with regard to the pace at which implementation of the various standards established under the Amendments is to proceed, the Environmental Protection Agency Administrator is directed to consider practicability, a major dimension of which is, undoubtedly, the implementation costs and the resulting economic effects.

Thus, it appears that as pressures for cleaning up the air have intensified, concerns of dire economic consequences of such action have also increased. Consequently, the Congressional Mandate to the APCO of the Environmental Protection Agency (EPA) even in the 1970 Amendments provide considerable flexibility for Administrative policymaking when policies will significantly affect the economy. It is safe to conclude that APCO would design policies that minimize any undesirable economic effects at the same time vigorously protecting the nation's health. The new legislation will doubtless result in a stepped-up program of control, modulated, to some degree, by concerns of adverse economic consequences.

To get on with the business of cleaning up in an economically humane fashion, a way must be found to separate the well-founded from baseless fears, and to tailor policies to mitigate insofar as possible, the undesirable consequences of air pollution control policies.

Virtually all of the economic policy questions concerning air pollution control which have been raised over the last four years, and which are continuing as a central concern, are questions of fact. Virtually everyone agrees that pollution control is, by itself, a good thing. Virtually everyone agrees that unemployment, high and rising prices, falling profits, and a falling growth rate are by themselves bad things. The disagreement arises when the extent to which good things, "air pollution control strategies," contribute to bad things, "unemployment, high prices, etc.," is considered.

Because these disagreements concern observable facts, it is in concept possible to think of an economic-environmental model that would identify and estimate these relationships. One could then manipulate air pollution control strategies in the model, observe the resulting employment, price, output, etc., changes holding all else constant, and infer something about the direction and magnitude of the economic impacts of air pollution control strategies.

The development and demonstration of such an Economic Model for assessment of abatement strategies for Air Quality Control Regions (AQCRs) is the theme of this report.

## 1.2 The APCO Economic Model System

An economic model is a simplified abstract version of the real world built on concepts of economic theory. A model is more than a hypothesis; it is a set of functional relations between the various elements of which an economy is composed. The crucial economic elements -- wages, capital, investment, income, consumption, employment and so forth -- are identified and relationships between them are postulated. For the purposes of any particular policy assessment, certain factors are assumed to be constant and the consequences of postulated relationships between policy and key economic indicators worked out for a variety of assumptions. The notion behind this procedure is that the many facets of economic life constitute a system and intervention such as by air pollution abatement strategies causes a variety of measurable economic effects.

APCO commissioned CONSAD Research Corporation, under subcontract to TRW Systems, Inc., for the development and demonstration of such an economic model as an operational analytical tool for abatement strategy assessment. This economic model initiated in 1968 as part of the Regional Air Pollution Analysis (RAPA) program focused on the regional economies of the various AQCRs. As such, it will be useful for assessment of control strategies at the regional level, where most of the implementation plans are prepared. However, there is an increasing interest in air pollution control policy decisions in the last three years at the Federal government level. Therefore, there has been correspondingly an increased focus in the model system described here toward the assessment of interregional and national economic effects in addition to regional effects. However, the model system developed by CONSAD is still a regional economic system with capabilities to measure, in a limited manner, the interregional and national effects. It is called the APCO Regional Economic Model System and has been demonstrated to some degree as an operational tool for control strategy assessment.

The rest of the report is devoted to a description of the context, scope, and operation in the use of this model system.

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# 2.0 THE RAPA PROGRAM AND THE REGIONAL ECONOMIC MODEL SYSTEM

## 2.1 Purpose of the RAPA Program

In July of 1968, the APCO initiated a systems analysis of regional air pollution control. It was clear, at the outset, that this study's contribution to the pollution problem's solution would be in the integration of contemporary air pollution control developments into a workable analytical tool, rather than in fundamental research areas. With this in mind, a tool was developed -- Regional Air Pollution Analysis (RAPA) -- to demonstrate the usefulness of looking at the many facets of the air pollution problems. With this tool, more precise estimates of the problem can be made, and more importantly, estimates can be made of specific approaches for the solution of the problems.

The RAPA program is a system of mathematical models arranged in a modular fashion and relating both engineering and economic effects of the analysis. Relations between the major components of the system are described in Figure 2.1.

Information on the effects of air pollution is reported in terms of air pollutant criteria, which are a compendium of today's knowledge of scientific findings on the range of adverse effects of specific air pollutants and combinations of pollutants on man and his environment. The

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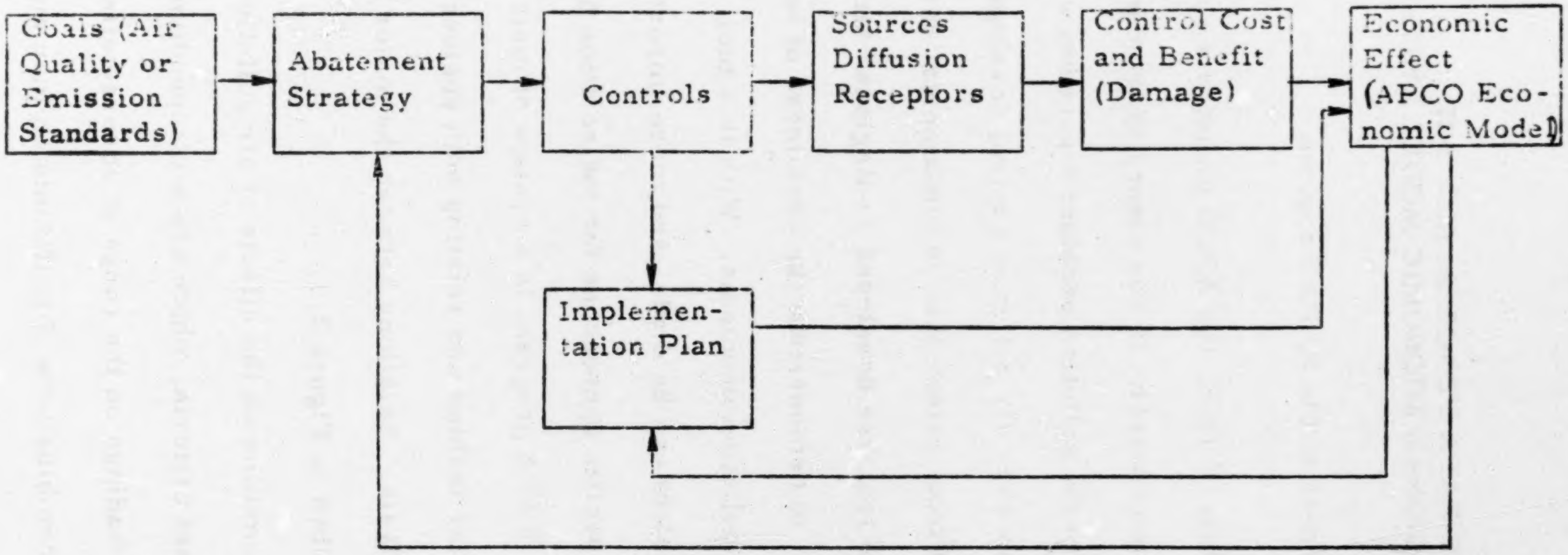
FIGURE 2.1

REGIONAL AIR POLLUTION ANALYSIS PROCESS


Goals (Air Quality or Emission Standards)
Abatement Strategy
Controls
Sources Diffusion Receptors
Control Cost and Benefit (Damage)
Economic Effect (APCO Economic Model)
Implementation Plan

evidence in the criteria documents, with respect to human health, animal health, plant damage, material damage and visibility, are not necessarily the lowest levels of exposure below which there are no adverse effects; however, they do provide quantitative guidance in the setting of regional air quality standards.

Air quality standards that are developed with the guidance of these air quality criteria are goals established for the protection of public health and welfare. They provide a basis for controlling existing sources of pollution emission and preventing future regional growth from adding to the pollution problem. Regional goals may reflect more than one air quality standard, insuring minimum air quality levels, as well as higher levels of air quality, to preclude any significant deterioration of existing high air quality levels.

On the other hand, engineering and economic information on control of air pollution is reported by the Federal government in terms of handbooks on available control devices such as filters and precipitators, and non-device control measures such as the use of low-sulfur content fuels or alterations to basic industrial processes that inherently cause less pollution.

The government's role starts with setting air quality standards which reflect goals for clean air within a specified time period. After the air quality standards are set, an effort is made to establish implementation plans which may set forth regulatory procedures, such as pollutant source emission standards to achieve air quality standards. Limiting pollutant emissions through source emission standards, along with other types of regulatory procedures such as zoning regulations or fuel restrictions, forms an abatement strategy designed to achieve regional air quality within a specified time period.

To accomplish the task of developing abatement strategies will require an extensive examination of the factors involved in the air pollution system, such as meteorology, air pollution control technology, air pollution growth trends, source emission inventories, existing regional air quality conditions, and regional economic impact.

The Regional Economic Model was expressly developed as a way to respond to these requirements of information on economic impacts of abatement strategies.

## 2.2 The Role of the Economic Model in RAPA

The recently enacted Federal air pollution abatement legislation requires business and industry to control the amount of pollutants that they discharge into the air. To industry, this requirement means that the production costs for the same amount of output produced prior to the legislation will be increased in proportion to the required investments to air pollution control equipment. Thus, certain industries and regions that have in the past enjoyed the economic advantage of low-cost production may face some degree of economic decline due to the requirements of pollution abatement.

There would be offsetting economic effects from air quality control strategies in such regions in at least two ways. First, there would be increased demand for the products of the industries that produce pollution control equipment and low pollutant fuels leading to increased output, employment, and income in those sectors. Second, a variety of general economic benefits result from pollution abatement. Some of those gains are increased labor productivity, reduced health expenditures, reduced outlays on physical maintenance of homes and plants, and savings in agricultural production activities. These gains would lead to increased consumption, output, employment and income, and would begin to offset the economic reductions resulting from the pollution control costs (as discussed above).

Consequently, air pollution abatement leads to changes in economic output, labor markets, the availability of capital, as well as redistributions within the entire economy. Further, the implementation of air quality programs would have a variety of other effects, such as tax base impacts on communities or variations in land-use and industrialization in various regions.

CONSAD Research Corporation has developed a regional economic model that will provide pollution abatement policy-makers capabilities to assess the effects of various pollution control strategies. The CONSAD model is intended to provide the following types of information for public-policy analysis:

- Regional economic changes (e.g., output, investment, employment, income, and consumption) expected to result from enforcement of varying abatement standards upon high-emission industries.
- Regional economic effects expected to result from reduction of industrial damage and growth in air pollution equipment industries.
- Fiscal effects of regional implementation of air quality control programs, including tax base impacts of economic change and the effects of tax credits upon economic change and the rate of achievement of emission standards in terms of the implementation plan.

With alternative abatement strategies at hand, not only associated direct control costs of each strategy, but also the measurement of the corresponding economic impacts of chain reaction throughout the region, will also provide useful information to the different levels of decision-making for the implementation plan. The changes in major economic indicators are the focal point in the analysis. For example, given that control costs directly increase production costs, then as profits decline, new investments may be reduced. Therefore, demands of the products from other firms and industries, and demands for labor are affected, resulting in changes in regional income and unemployment levels. On the other hand, those industries (and individuals) that originally suffer damages and pay additional costs due to the polluted air may start to enjoy some economic gains from the air pollution control. Meanwhile, fuel substitutions might occur in some firms, especially those in the electric power industry. The demands for pollution control equipment will also result in a new series of product demands within and outside the area. Basically, there is a shift in economic structure of the region.

Abatement strategies not only cost more to the high emission industries, but also result in an initial decline in regional employment and income. Decision-making is required in the public sector to weigh these adverse consequences. The trade-off between the total costs and benefits to the entire regional community may depend upon the information from these measured economic impacts of alternative control strategies. Tax policies and techniques for financing and distributing air pollution control costs can be determined through a full examination of the total impacts to the community.

During the first year of the RAPA program, CONSAD developed a model of the economic effects of air pollution control (Regional Econometric Model) of the St. Louis metropolitan region based on time series data.* During this second year of the program, the aim was to focus on the development of a model which can be applied to the major cities in this country. This resulted in estimation of a cross-sectional economic model for the 31 largest Standard Metropolitan Statistical Areas (SMSAs) across the country. The roles of Keynsian theory and regional export base theory will be central as they were in the St. Louis time series model. However, the entire equation system has been reformulated in order to integrate the cross-sectional structure into the model.

In the current year (Phase III), the 31 AQCR Model System has been extended further and utilized for policy assessment. The nature and scope of this extension and utilization of the Regional Model is described in the next section.

## 2.3 The APCO Economic Model System (Phase III)

In the current year (Phase III), two types of activities have been carried out:

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*CONSAD Research Corporation, Structure Requirements of an Econometric Model of St. Louis SMSA, prepared for TRW Systems, January, 1969, and Final Version of the CONSAD Regional Econometric Model as Applied to the St. Louis SMSA for Air Pollution Control Analysis, May, 1969. (A summary of these reports appears in Appendix A.)

- Further model development, and
- Preliminary demonstration of model use and assessment of three trial strategies.

These activities are outlined in Figure 2.2.

### Model Development

The APCO Regional Economic Model developed in the third year (Phase III) by CONSAD is a logical extension of the concepts and empirical work of the first two years into an operational tool amenable to assessment of various control strategies. In particular, it builds on and extends the Phase II 31 AQCR Model in three important dimensions.

First, the Phase III model is extended to cover 100 AQCRs. These 100 AQCRs account for over 65 percent of the national output. Thus, the APCO model will cover a major portion of the economic activity in the nation.

Second, the Phase III model overcomes a major drawback of the 31 AQCR model, which treats each AQCR as an isolated region. In reality, economic effects attendant on pollution abatement are not localized. Price increases in certain industries, the growth of control equipment industries or demand spurred by reduced expenditures on health, etc., in one region will have feedback effects on the economies of other regions. The Phase III APCO Economic Model System uses a national Input-Output (I-O) system linked to a regional market

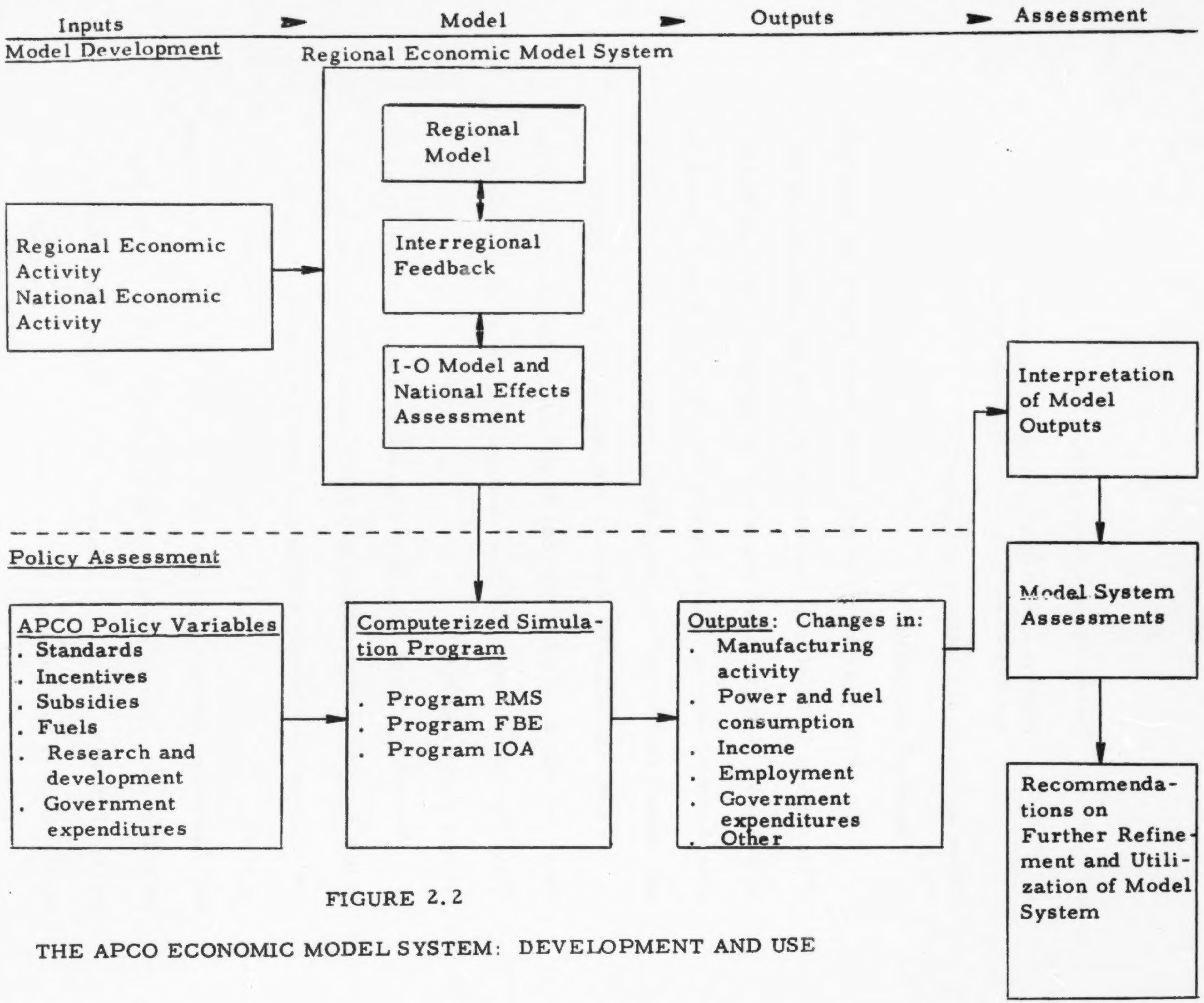

Inputs
Model
Outputs
Assessment
Model Development
Regional Economic Model System
Regional Economic Activity
National Economic Activity
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Interpretation of Model Outputs
Model System Assessments
Recommendations on Further Refinement and Utilization of Model System
Policy Assessment
APCO Policy Variables
. Standards
. Incentives
. Subsidies
. Fuels
. Research and development
. Government expenditures
Computerized Simulation Program
. Program RMS
. Program FBE
. Program IOA
Outputs: Changes in:
. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other

FIGURE 2.2

THE APCO ECONOMIC MODEL SYSTEM: DEVELOPMENT AND USE share matrix to capture these interregional feedback effects and encompasses the 100 AQCRs as an interrelated system of regions.

Third, the Phase III model incorporates a regional fuel demand submodel as a component of the Regional Economic Model System. As air pollution control policy is implemented, sulfur content in coal and fuel oils will greatly affect their price in view of increased demand for low sulfur fuels and their limited supply. Prices of natural gas and electricity will also tend to change. Industries will choose an optimal combination of fuels and electricity which minimizes the total cost of energy, to the degree substitution is possible. The fuel demand model will describe these relationships.

Figure 2.2 shows the three modules -- Regional Model, Interregional Feedback, and the National I-O Model -- of the Regional Model System that is described in detail in the next chapter. It should be noted a link is needed to a national macro model to capture the overtime and structure change of national effects. Such a link to the Office of Business Economics (OBE) Quarterly Model was assessed for feasibility in this regard. This effort forms the theme of Chapter 4.

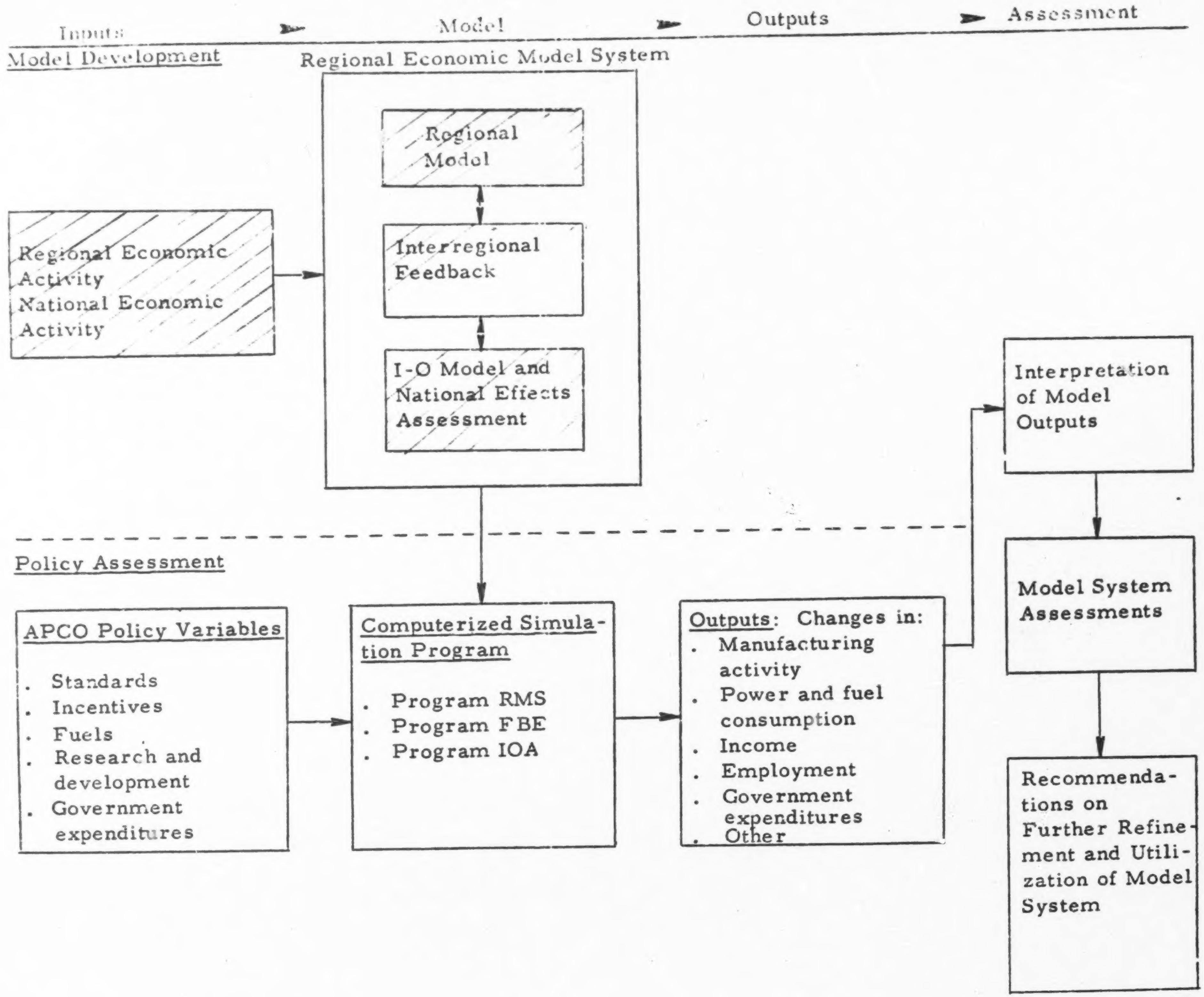
### Policy Assessment

A simulation program consisting of three modules corresponding to the three modules of the Regional Model System was prepared. This program is a flexible, efficient tool to estimate changes in the regional and national economies when alternative abatement strategies are specified. The control strategies have to be translated into variables consistent with the model structure before the simulation can be initiated. Such specification and use of the three control strategies specified by APCO for input into the model is described in Chapter 5.

Chapter 6 identifies a wide range of model outputs resulting from the three strategies. It also develops an approach to organize in a preliminary way these outputs for analysis. Finally, a tentative interpretation of the complex economic effects of the three strategies is provided.

An assessment of the model structure, data and simulation program forms the theme of Chapter 7.

Chapter 8 explores the utilization potential of the APCO Regional Economic Model System and advances recommendations for further utilization of the model.


Inputs
Model
Outputs
Assessment
Model Development
Regional Economic Model System
Regional Economic Activity
National Economic Activity
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Policy Assessment
APCO Policy Variables
. Standards
. Incentives
. Fuels
. Research and development
. Government expenditures
Computerized Simulation Program
. Program RMS
. Program FBE
. Program IOA
Outputs: Changes in:
. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other
Interpretation of Model Outputs
Model System Assessments
Recommendations on Further Refinement and Utilization of Model System

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# 3.0 MODEL DEVELOPMENT AND FORMULATION

## 3.1 The Model in General

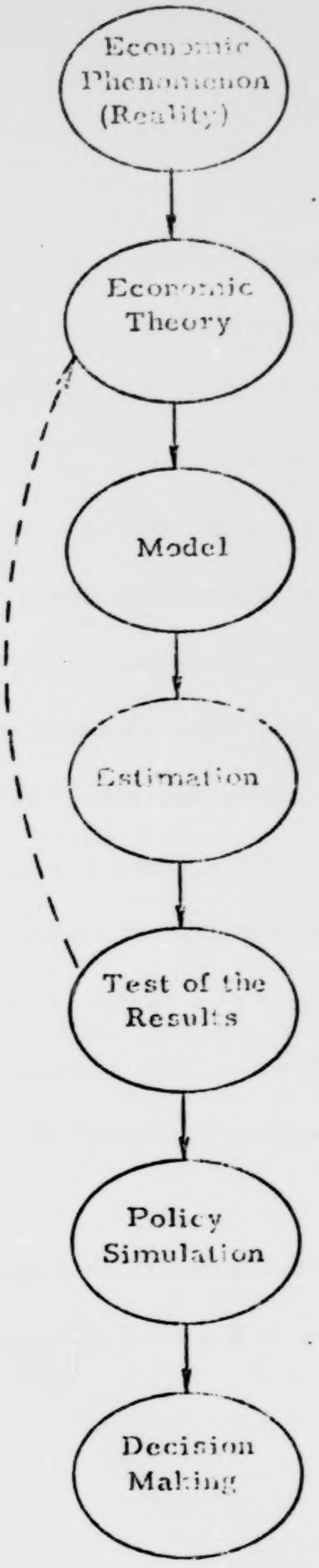
A model is essentially a representation of a real world phenomenon devoid of those elements deemed irrelevant or unimportant for the purpose at hand. A model consists then of variables embedded in mathematical formulae (structural relationships), numerical constants (parameters), solution methods (algorithms), and processes used for establishing the values of parameters (calibrating procedures). A variable is a measurable quantity in which one has some interest and which varies from observation to observation. Variables are to be distinguished from a parameter which essentially describes the structure. Parameters change slowly over time (in response to a structural change or break) and in this sense are "less variable variables."

An econometric model generally consists of a system of equations embodying a prior reasoning of economic theory. This reasoning is given empirical content by estimating and testing the model through statistical methods.

In brief, an econometric model for policy simulation purposes includes the following logical steps as shown in Figure 3.1.

FIGURE 3.1

ECONOMIC MODELLING FOR POLICY SIMULATIONS


Economic Phenomenon (Reality)
Economic Theory
Model
Estimation
Test of the Results
Policy Simulation
Decision Making

**Step 1**: Hypothesis: Abstract relations between key variables

**Step 2**: Formulation: Mathematical formulation of equation system includes:
endogeneous (output) variables
exogeneous (input)

**Step 3**: Estimation: Data collection, statistical methods, and computation

**Step 4**: Evaluation: Test of economic theory by statistical methods, acceptable or not

**Step 5**: Simulation: Impact simulation of different strategies

**Step 6**: Use: Information from results of policy simulations used in decisions

From the complexity of real economic space, economic theory develops by simplification of the relationships between key variables under investigation. For example, the relation between income and consumption of society is isolated from other numerous factors and presented under a set of assumptions.

The second step includes a mathematical formulation of economic theory into a model which consists of a set of equations. In this mathematical model, endogenous variables will be determined by the model using a set of exogenous variables which are given outside of the model. In other words, exogenous variables provide model input and endogenous variables the output of the model. A policy-oriented model usually integrates the policy questions or variables of the structure of the model as well.

In the case of a mathematically formulated model, empirical data are corrected and estimation of the model parameters by statistical methods takes place as in Step 3.

In Step 4, the results of statistical estimation are assessed by evaluation criteria from probability theory to determine whether the results are acceptable. If not, theoretical assumptions in Step 1 will be rejected and reformulation is in order.

After an acceptable model is "empirically" obtained, the model is ready for policy simulation. Policy, by itself, is an exogenous "shock" to the model to observe the change of endogenous variables in the model. It can be in the form of a change in exogenous variables or an exogenous information of change in the parameters of the model.

Outputs from the simulation provide the information of the endogenous variables before and after the policy simulation for evaluation of policy impact to the economic system under study.

## 3.2 The APCO Economic Model System

The APCO Economic Model System consists of two major components, namely, a 100 AQCR regional model and interregional feedback from a national I-O model, as shown in Figure 2.2. The modules comprising both these major components are also indicated in Figure 3.2. A generalized description of the model system appears in this section, and a more detailed development and estimation of the model is provided in Appendix A through Appendix D.

### 3.2.1 The Regional Model

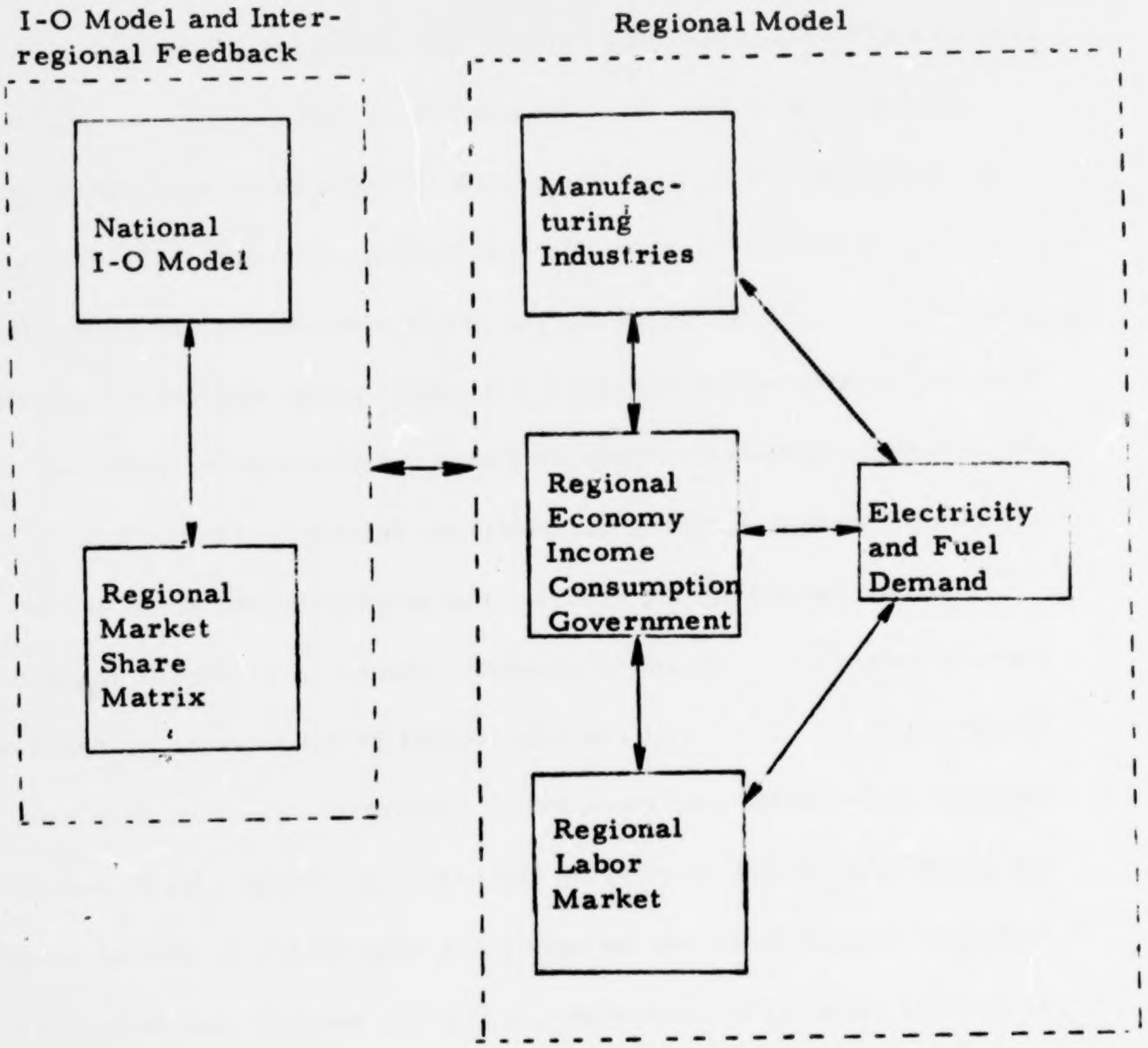
There is a fundamental difference between the economy of an AQCR and the national economy. The former is an open economy where growth and development are closely related to its capability to carry on external trade with other regions. The latter is rather more self-contained by its nature. The concept of "export-base" or economic base theory has traditionally been the central guiding concept in the description of urban economies. In line with this concept, this study treats manufacturing industries as export-oriented industries. The growth of the manufacturing industries leads to the growth of the regional economy. This model structure is consistent with the familiar Keynsian-type trade multiplier in an open economic system. Consequently, in Figure 3.2, the manufacturing industry module feeds into the regional economy, and growth of manufacturing industry and regional economy determine the regional employment in the regional labor market. By the same token, production and consumption activities are related to the demand for electric power and fuels. All these relationships have been formulated into a mathematical model as shown in Figure 3.4, using the notations defined in Figure 3.3.

In the manufacturing module, the production relations of the manufacturing industry are presented. Output is related to the production factors: labor and capital. Gross profit is given as residual between value-added and wage bill. Investment behavior is related to the profit and capital stock from the previous period. With new investment expenditures and adjustment of depreciation, capital stock of present capacity is determined. Finally, employment in manufacturing sectors is derived from the level of production and wage level.

In the regional economy module, regional income is determined by the level of manufacturing production, regional consumption

## FIGURE 3.2

## MAJOR COMPONENTS OF THE MODEL


I-O Model and Inter-regional Feedback
Regional Model
National I-O Model
Regional Market Share Matrix
Manufacturing Industries
Regional Economy Income Consumption Government
Electricity and Fuel Demand
Regional Labor Market

## FIGURE 3.3

## NOTATION OF THE REGIONAL MODEL VARIABLES

NOT REPRODUCIBLE

| | |
|---|---|
| $V_{ij}$ | value-added by industry j of ith AQCR |
| $K_{ij}$ | capital stock by industry j of ith AQCR |
| $N_{ij}$ | employment by industry j of ith AQCR |
| $I_{ij}$ | investment expenditure by industry j of ith AQCR |
| $\Pi_{ij}$ | capital share or gross profit by industry j of ith AQCR |
| $W_{ij}$ | average wage by industry j of ith AQCR |
| $Y_i$ | regional personal income of ith AQCR |
| $C_i$ | regional consumption expenditure of ith AQCR |
| $G_i$ | local government expenditure of ith AQCR |
| $T_i$ | local government revenue of ith AQCR |
| $\overline{N}_i$ | employment by industries other than manufacturing industries of ith AQCR |
| $N_i = (\sum_{j=1}^{19} N_{ij} + \overline{N}_i)$ | total regional employment of ith AQCR |
| $L_i$ | regional labor force of ith AQCR |
| $Q_i$ | total regional consumption of electric power in ith AQCR |
| $Q_{ij}$ | electric power consumed by industry j of ith AQCR |
| $Q_{ci}$ | electricity consumed by residents of ith AQCR |
| $\overline{Q}_i$ | electricity consumed by industries other than manufacturing industries of ith AQCR |
| $q_r$ | price of fuel type r of ith AQCR, type of fuel including coal, coke, fuel oil and natural gas |
| $E_{rij}$ | demand of fuel, type r by jth industry by ith AQCR |

$i = 1, \ldots, 100$ 100 AQCR's

$j = 1, \ldots, 19$ which is two-digit manufacturing industries

## FIGURE 3.4
## THE REGIONAL MODEL FORMULATION

NOT REPRODUCIBLE

### I. Manufacturing Industry

$$V_{ij}(t) = A_{ij} N_{ij}^{\alpha_j}(t) K_{ij}^{1-\alpha_j}(t) \qquad j=1,\ldots,19 \tag{1}$$

$$\Pi_{ij}(t) = (1 - \alpha_j) V_{ij}(t) \qquad j=1,\ldots,19 \tag{2}$$

$$I_{ij}(t) = f(\Pi_{ij}(t), K_{ij}(t-1)) \qquad j=1,\ldots,19 \tag{3}$$

$$K_{ij}(t) = K_{ij}(t-1) + I_{ij}(t) - d_j K_{ij}(t) \qquad j=1,\ldots,19 \tag{4}$$

$$W_{ij}(t) = f(W_{ij}(t-1), u_i(t)) \qquad j=1,\ldots,19 \tag{5}$$

### II. Regional Economy

$$Y_i(t) = f(C_i(t), \sum_j V_{ij}(t), G_i(t)) \tag{6}$$

$$C_i(t) = f(Y_i(t), C_i(t-1)) \tag{7}$$

$$G_i(t) \quad f(Y_i(t)) \tag{8}$$

### III. Regional Labor Market

$$\overline{N}_i(t) = f(Y_i(t) - \sum_j^{19} V_{ij}(t) \tag{9}$$

$$N_i(t) = \overline{N}_i(t) + \sum_j^{19} N_{ij}(t) ) \tag{10}$$

$$u_i(t) = \frac{L_i(t) - N_i(t)}{L_i(t)} \tag{11}$$

$$L_i(t) = f(N_i(t), u_i(t)) \tag{12}$$

FIGURE 3.4 (continued)

## IV. Electricity and Fuel Demand

NOT REPRODUCIBLE

(13) $Q_{ij}(t) = f(V_{ij}(t))$ $j=1, \ldots, 19$

(14) $Q_{cj}(t) = f(C_i(t))$

(15) $\overline{Q}_i(t) = f(Y_i(t) - \sum_j V_{ij}(t))$

(16) $Q_i(t) = \sum_j Q_{ij}(t) + Q_{ci}(t) + \overline{Q}_i(t)$

(17) $\sum_r E_{rij} \cdot q_{ri} = a_j V_{ij}$ $j=1, \ldots, 19$

(18) $Z_{ij}(t) = B_{ij}(t)\, E_{1ij}^{\beta_{1j}},\ E_{2ij}^{\beta_{2j}},\ \ldots\ E_{5ij}^{\beta_{5j}}$ $j=1, \ldots, 19$

expenditures and local government expenditures. On the other hand, regional consumption is related to the regional income, and government expenditures is related to the government revenues.

In the regional labor market module, employment by industry, other than manufacturing industry, is derived from the income generated from non-manufacturing sectors. Regional employment, which is the summation of employment from manufacturing and non-manufacturing industries, and unemployment rate, determines the regional labor force in each AQCR.

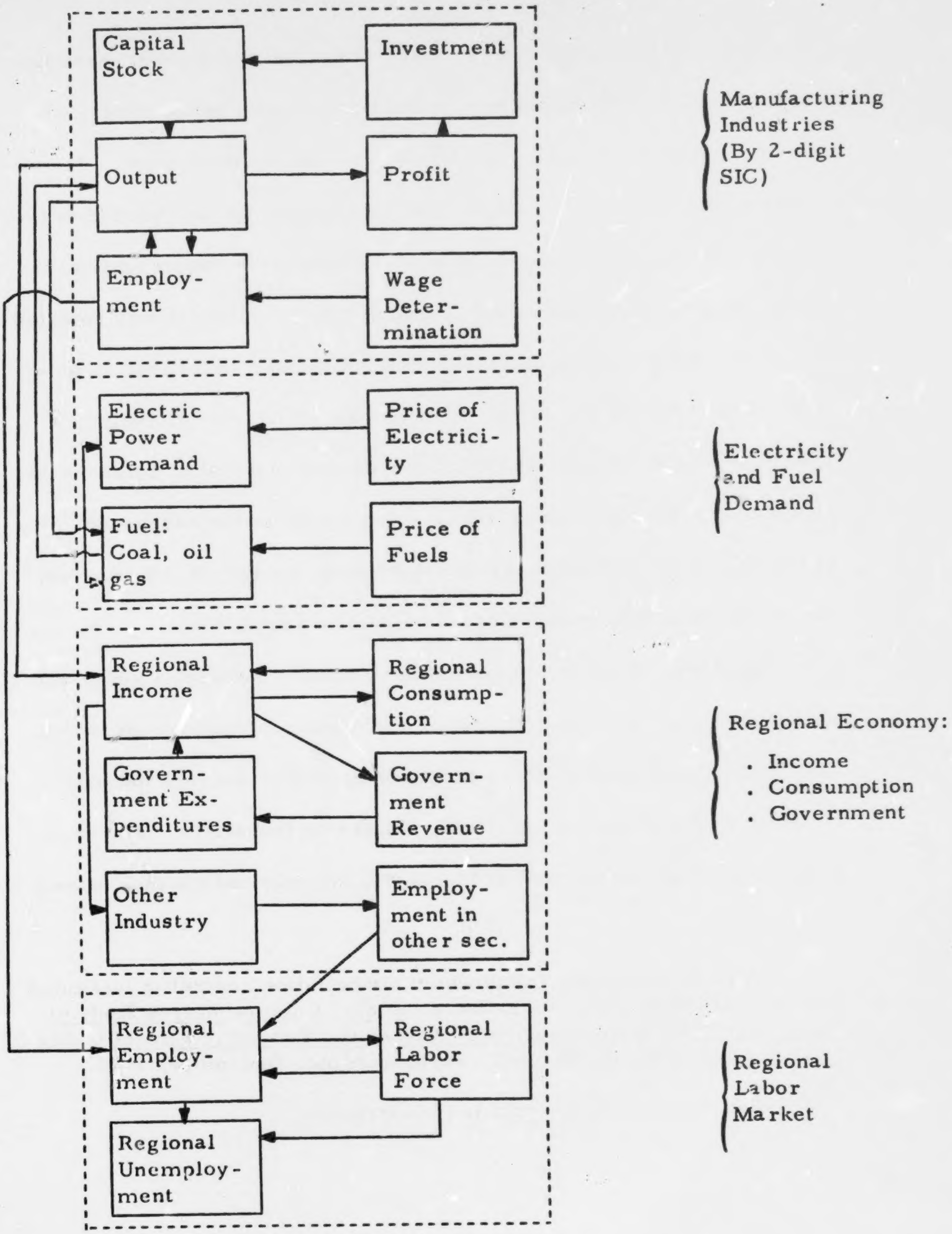
Finally, electricity and fuel demand modules provide the demand of electricity and fuel derived from production and consumption activity of the region. A substitutional relationship between different types of fuels is also included.

A more detailed look at the regional model which comprises 162 equations is provided in Figure 3.5.

### 3.2.2 I-O Model and Interregional Feedback

As emphasized earlier in the model formulation, a region's growth is closely dependent upon its capability to carry on external trade with other regions. A national input-output system is introduced to serve the role of external market for the regional economy described in the regional model, and also, hopefully, to measure the structural change of the national economy upon air pollution control to the 100 AQCRs.

FIGURE 3.5
REGIONAL MODEL -- A MORE DETAILED LOOK


Capital Stock
Investment
Output
Profit
Employment
Wage Determination
Manufacturing Industries (By 2-digit SIC)
Electric Power Demand
Price of Electricity
Fuel: Coal, oil gas
Price of Fuels
Electricity and Fuel Demand
Regional Income
Regional Consumption
Government Expenditures
Government Revenue
Other Industry
Employment in other sec.
Regional Economy:
. Income
. Consumption
. Government
Regional Employment
Regional Labor Force
Regional Unemployment
Regional Labor Market

The relation between a national I-O system and a cross-sectional regional model of Keynsian-type formulation can be better explained from policy questions to be answered from this model system. The regional model developed in Phase II is appropriate for an isolated region without interregional feedback scheme, although the export activity is explicitly treated. When an air pollution control policy is implemented across the nation, costs increase. The production will result in an upward shift of the supply curve. Whether an industry or an individual firm may be able to pass on the increased cost per unit of output is dependent upon the elasticity of demand and supply of the corresponding products. If price changes are obtained from exogenous information,* the equilibrium supply of the products will be known.**

However, price increases in high emission industries under air pollution control will not only reduce the demand of their products but also affect the demand of those products which are the intermediate products in the production of the high emission industries. For example, a higher price for steel products will not only reduce the demand for steel but also affect sales in transportation, coal products, and other materials and services related to the steel industry. Further, such effects originating in a given region (or AQCR) in the nation will not be limited to the region but would affect the economic activity in other regions (or AQCRs) and in all likelihood, create a feedback to the region. *

---

*A study of price markup which air pollution control is instituted has been reported in D. A. LeSourd, et al., Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Effects of Air Quality Standards, Research Triangle Institute, December, 1970.

**See Appendix C for detailed illustration.

For a limited number of regions, the formulation of an interregional I-O system is perhaps feasible. However, a 20-sector regional I-O system with 100 regions, the size of the matrix will be 2000 x 2000 (with such detailed information largely non-existent).

An alternative formulation was consequently necessary. A national input-output system linked to a regional market share matrix was used to capture the regional feedback. It is argued that the regional share of the national market by industry (termed as the "location quotient"**) is relatively stable. For example, if steel production in the Pittsburgh AQCR is 12 percent of the nation's steel product, then 12 percent of a change in the national steel market will have an affect on the Pittsburgh AQCR. This concept is particularly useful for a cross-sectional model which deals with the geographic distribution of economic activity at a given period of time.

---

*These interregional feedback phenomenon were observed in a pioneer study by Ronald E. Miller, "Interregional Feedback Effects in Input-Output Models: Some Preliminary Results," Papers, Regional Science Association, Vol. 17, 1966.

**A location quotient is the ratio of the regional activity level in an industry to that in the nation in that industry.

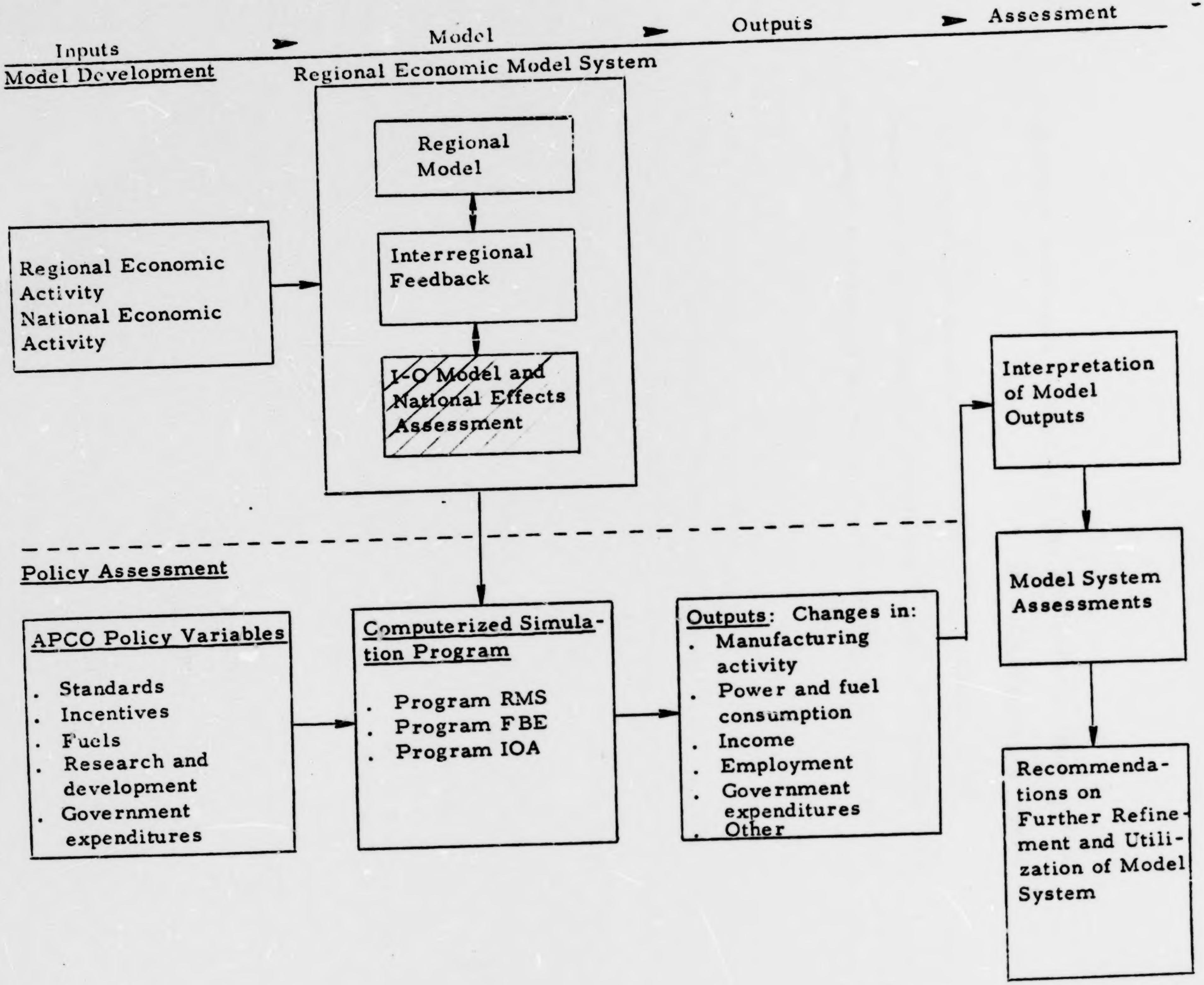
In brief, using exogenous information on price changes in high emission industries occasioned by air pollution control, the high emission industries in each AQCR will fall in output to the point corresponding to an upward shifting supply curve and the new price after control. An aggregation of changes in regional production for each high emission industry will give the change of demand in the nation. By use of the national I-O system, the impact of changes in high emission industries on other industries can be measured. Finally, through the use of regional market share matrix, the national impact can be distributed to each AQCR as the net interregional feedback from the other regions under study (99 AQCRs) and the rest of the nation.

## 3.3 Empirical Estimation

A detailed account of the data used in the model and methods of statistical estimation is provided in Appendices C, D and E. It is worth noting here that the economic data used were for 1967.

In general, the equation in each of the modules shown in the regional model component in Figure 3.2 is solved simultaneously. However, the modules themselves are related recursively. The model system appears to perform well on criteria of plausibility, explanatory power, and reliability.

The I-O model is a 42-sector model obtained by collapsing the 1963 national I-O table. The details of the development of this model and the interregional market share matrix are described in Appendix D.


Inputs
Model
Outputs
Assessment
Model Development
Regional Economic Model System
Regional Economic Activity
National Economic Activity
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Interpretation of Model Outputs
Model System Assessments
Recommendations on Further Refinement and Utilization of Model System
Policy Assessment
APCO Policy Variables
. Standards
. Incentives
. Fuels
. Research and development
. Government expenditures
Computerized Simulation Program
. Program RMS
. Program FBE
. Program IOA
Outputs: Changes in:
. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other

# 4.0 PRELIMINARY STUDY OF A MODEL FOR NATIONAL ECONOMIC EFFECTS ASSESSMENT

## 4.1 The Transition from Regional to National Policy Analysis: Background

Over the past three years, there is an increasing interest in air pollution control policy decisions at the Federal government level. This transfer is institutionalized under the Clean Air Amendments of 1970, which delegates significant new authorities and responsibilities for cleaning up the nation's air resource to APCO of EPA. Directly or indirectly, APCO decisions will result in billions of dollars of emission control expenditures each year. As air quality is changed due to these control expenditures, additional billions of dollars worth of changes in production and consumption patterns can be expected to ensue. Taking the longer view, changes in technology fostered by Federal government-sponsored and private research and development can be expected to make revolutionary changes in modern living patterns (e.g., transportation and energy).

Paralleling this trend, there has been a shift of emphasis in CONSAD's efforts to develop a model for assessment of the economic effects of air pollution control. During the first year of the project, a time series econometric model of a single region -- the St. Louis metropolitan area -- was constructed and the economic impacts of alternative control strategies for that region were simulated. Over the second year of the project, a model like the St. Louis model was built for 31 AQCRs using cross-section data.

Simulations of these regional models, in the context of over-increasing emphasis on a Federally-coordinated national program of air pollution control, highlighted the need for two types of improvements in the scope and structure of these models.

First, the regional model was structured as though AQCRs were economically independent of one another. There was no allowance for interregional effects. If, for example, Region A instituted air pollution control and in order to do so imported air pollution equipment from Region B, the model simulated the economic impact of Region A's program on Region A alone, and not on Region B. Thus, the regional model gave no indication of the increase in employment in Region B resulting from the increased production of air pollution control equipment for export to Region A. There was, therefore, a source of pessimistic bias in the statement of economic effects of air pollution abatement embedded in the very structure of the model.

Second, the models at the end of the second year focused only on the economic impacts of control expenditures and accounted in no way for any benefits which might result from air quality improvement. This again tended to cause unjustifiably pessimistic conclusions about the economic effects of air pollution control.

During the current year, CONSAD approached the problem of eliminating these biases and making some preliminary assessment of the national impact of air pollution control in two ways. First, the cross-section Regional Model was restructured to eliminate, insofar as possible, the pessimistic bias induced by structural exclusion of interregional feedback effects and benefits and to permit preliminary estimates, a national I-O model has been introduced to capture: (1) a preliminary estimate of structural changes in the national economy, and (2) an interregional feedback scheme to the AQCRs.

Second, the feasibility and desirability of an expressly national model to be interconnected with the current regional model was investigated in considerable detail.

It is the primary purpose of this chapter to present the findings of this evaluation study. It opens with a brief discussion of CONSAD's attempt to use an existing national econometric model for making preliminary estimates of national effects of alternative national control strategies.

Given the nature and difficulties of access of existent models, the chapter next explores the feasibility of the development of a national model specifically structured for air pollution policy assessment.

## 4.2 The OBE Quarterly Model

As a part of Phase III of the RAPA project, CONSAD investigated the possibilities and potentials of adding another model to the Regional Economic Model System for the express purpose of assessing the national economic effects of air pollution control. CONSAD planned the use of the OBE Quarterly Econometric Model to make preliminary estimates of national economic effects.

A brief review of the nature of concern with a national macro model will be a useful prelude to the discussion of the OBE model utilization.

The national economic system and the environment conditions form two interrelated dynamic systems. Pollution is a by-product of economic activity. In this broad sense, growth of GNP and hence the industrial component are closely related to the environment conditions in the future. On the other hand, implementation of a given emission (an air quality) standard, possibly involves an over time policy planning and stimulates a dynamic economic impact to the nation. Even if the control technology is available, an overnight switch of entire production line, for example, a highly efficient automobile engine, may be economically impractical. The question of tax policy, choice of evaluation criteria, or optional time table of a given standard are all key questions involved in the trade-off between the growth of GNP and a better or worse off environmental condition of the nation.

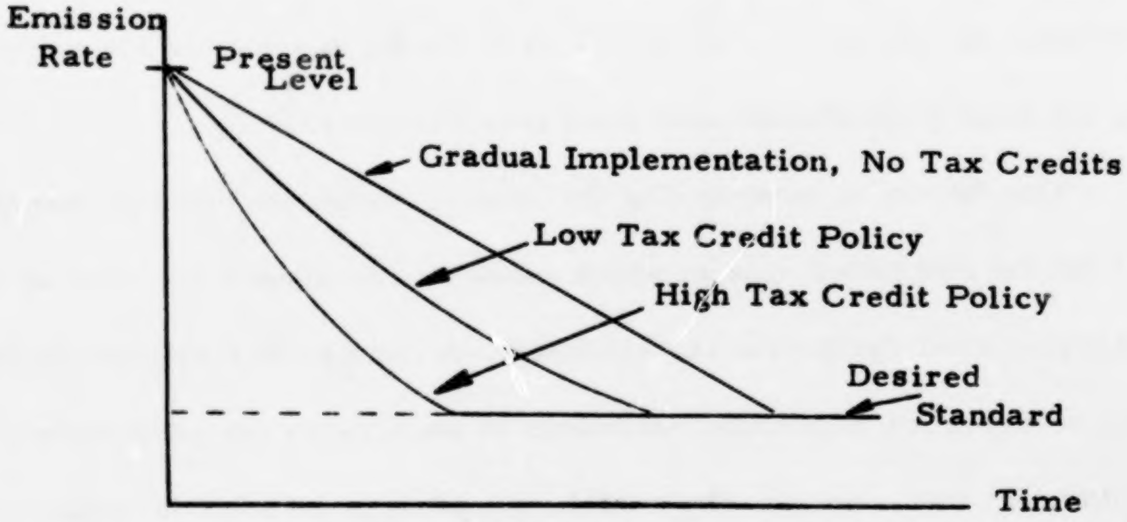
For example, given a national standard for a certain type of emission, there are a set of "implementation phase." Each implementation phase may be thought of as depicting a schedule for achieving air quality standards over time (see Figure 4. 1).

One factor in determining the rate of implementation of standards will be the estimated rate at which industry can absorb the cost of air quality control equipment installations. A time series national model may be designed to provide estimates of such rates for each industrial sector. In this manner, the model may provide data for facilitating the current process of implementation planning.

The future process of implementation planning may be enhanced by providing APCO with additional control measures for mounting an implementation strategy. One such measure mentioned in the past at the Federal level is the provision of tax credits to industries that invest in costly pollution control equipment. One effect of the proposed measure would be to accelerate the rate at which industry can absorb

FIGURE 4.1

EFFECT OF TAX CREDIT STRATEGIES
UPON IMPLEMENTATION PLAN



pollution control costs, and this, in turn, would increase the rate at which desired standards can be implemented.

Although acceleration of the feasible implementation schedule will occur under a tax-credit strategy, the effectiveness of this measure will depend upon the growth rate of industrial composition of the nation. The impacts upon the feasible rate of implementation that may be expected of a proposed tax credit strategy may be estimated with a national model.

On the other hand, the regional model developed in the last chapter is a cross-sectional model, although some lagged variables are included. It is argued that economic impact of air pollution control strategies can be described in two facets, namely, spatial impact of resource allocation and over time impact related to the growth of the economy. The regional model is particularly useful as demonstrated in Chapter 6 when a region-by-region differential of control impacts are of concern. It will be shown that while the aggregate net change on all 91 AQCRs under study is an increase of unemployment rate of 0.5 percent (3.5 to 4 percent), the unemployment rates in some of the AQCRs with concentrations of high emission industries will be 2 percent or more. Some other AQCRs are shown to be even "better off" in terms of unemployment effects under the same air quality standards.

But, the limitations of the regional model is also clear; a cross-sectional model needs different sets of economic data over time to provide a preliminary picture of dynamic impact of the air pollution control. Thus, it requires projections of large sets of data, and restricting thereby the accuracy of the model.

Thus, it appears that a cross-sectional regional model linked with a time series national model will be an ideal system for the study of economic effects.

It was with this objective that CONSAD began the exploration of the link-up and use of an extant national model to the Regional Model. The candidate for this experiment was the OBE Quarterly Model. This model was to provide a "quick look" at the national effects over time. The nation model will cover the rest of the nation other than the AQCR and hopefully a preliminary over time economic impact of air pollution control will emerge.

An intensive study of the structure of the OBE model, however, revealed a number of structural properties which rendered it not an entirely desirable tool for national effects assessment. In particular, the model is structured primarily for the purpose of making short-term (roughly eight quarters) forecasts of the effect of conventional government fiscal and monetary strategies. Both the temporal and industrial aggregation of the model are inappropriate to simulations of the national economic effects of air pollution control.

In contrast to the high degree of time disaggregation of the OBE model, it exhibits a high degree of industrial aggregation. No differentiation is made, for example, of investment by industrial sector, GNP by sector or employment by sector. Since a principal concern of APCO must be the effect of its policies on particular industries, the OBE model must be judged less than satisfactory for APCO strategy analysis purposes.

Meeting with OBE personnel generally confirmed CONSAD's findings. Indeed, OBE professionals had such serious reservations about the appropriateness of the model for air pollution control strategy simulations that access to the model was effectively refused. It would seem, therefore, that if an effective vehicle is to be sought for national economic effects assessment, APCO must look to some other national model, or perhaps consider building one expressly for its purposes.

Given the results of the OBE model applicability to air pollution control strategy assessment, it appears appropriate to inquire whether other models are to be explored or whether a special model needs to be developed for APCO use. Before this query is addressed, it will be useful to identify the characteristics of what CONSAD believes to be a desirable national model.

## 4.3 Desired Attributes in a National Model

Ideally, a national model and the current Regional Model would be moulded into one large interdependent system of models. In rough terms, the system of models would be composed of three submodels, each of which would pertain to a particular geographic area:

- the nation,
- specific AQCRs, and
- the rest of the United States not in AQCRs specifically included in the model.

CONSAD stresses the importance of retaining specific regions within the model since the economic effects of air pollution control have been found to be strikingly different from region to region. A solely national picture would thus be misleading in important ways.

Submodels (1) and (2) of the ideal model structure would have stochastic equations. Submodel (3) would be made up wholly of identities. Each of the three submodels would be sectored conformably to facilitate interconnection. The submodels would then be interconnected into one large model as indicated in the following simple Keynesian model.

Submodel 1

$$Y_N = C_N + I_N$$

$$C_N = a_N + b_N Y_N + e_N$$

where: N stands for nation, and

Y, C and I are income consumption and investment, respectively.

Submodel 2

$Y_1 = C_1 + I_1$

$C_1 = a_1 + b_1 Y_1 + e_1$

where: "1" stands for region i.

Submodel 3

$Y_0 = Y_N - Y_i$

$C_0 = C_N - C_1$

where: "0" stands for the nation that is outside the AQCRs.

Submodel (2) would consist of the CONSAD's regional model for all AQCRs currently has or will develop, further refined to incorporate interregional flows of air pollution control factors. Submodel (1) will be estimated according to the sectoring and specification necessary for air pollution control study.

The output of this integrated model would be a comprehensive and logically consistent forecast of the economic and gross environmental effects of air pollution control programs for each of the specifically included AQCRs, for the nation, and for all other areas of the United States not in the specifically included AQCRs.

Submodels (1) and (2) should be sectored at least into three broad categories, namely, sectors affected by pollution, sectors affecting pollution, and environment sectors which provide gross environmental indicators related to economic variables. Consideration should be given to the sectors affected by the level of pollutants. For example, reduction of agriculture productivity, health and productivity losses, extra household maintenance, cleaning services are highly related to the level of pollutants in ambient air. These effects can be reflected in the production function of agriculture.

For sectors affecting pollution, emission of pollutants from a given source depends upon the level of output. Air pollution abatement will lead to cost increases in the high emission industries and be reflected in price increases and in changes in interindustrial structure. Such high emission industries include steam-electric power, iron and steel mills, petroleum refining, sulfate pulp mills, hydraulic cement manufacturers, gray-iron foundries, etc. For these industries, demands for low sulfur fuel and control devices will depend both on output level and emission standards. Environmental sectors, since pollution and economic activity are interrelated, should also contain a set of equations predicting emission from production and level of control activity. These sectors would also include supply and demand relations of control device and low sulfur fuels.

Besides the sector specification, environmental variables should be explicitly integrated into the related equations. The following examples will provide some ideas on this approach.

### Sectors Affected by Pollution

The production function of the agriculture sector can be specified as follows:

$$X = f\ (K,\ L,\ P)$$

where X, K and L are output, capital and labor, respectively, and P is measurement of pollution concentration such that:

$$\frac{\partial X}{\partial P} < 0$$

Reduction of emission increases output level, such treatment is quite similar to the technical change introduced in production function.

In the consumption functions, benefits from air pollution control (B) can be introduced as follows:

$$C = f\,(Y,\ B)$$

$$B = f\,(P)$$

$$\frac{\partial B}{\partial P} < 0$$

Reductions in air pollution levels (P) will save expenditures on health, household maintenance, cleaning service, etc. Types of benefits and consumption expenditures can be further divided if such data are available.

### Sectors Affecting Pollution

Production functions of the high emission industries can explicitly include low sulfur fuel (S) and control devices (D) as additional factors of production:

$$X = f\ (K,\ L,\ S,\ D)$$

From these production functions can be derived projections of emissions and projections of the demand for inputs for air pollution control.

In sum, the ideal model is a comprehensive model, fairly complete not only in its coverage of national economic phenomena, but also regional economic phenomena and gross environmental phenomena.

## 4.4 Data Availability and Reliability

Apart from the theoretical and structural advantages of a national model in dealing with the dynamic nature of the economic impacts of air pollution control, a major profit of the national modelling is the ability to capitalize on the rich and reliable economic data and the control input data available at the national level.

It often happens that data on a two-digit SIC industry in a given AQCR is not disclosed in order to protect the financial conditions of firms when less than four operate in that AQCR in that industry. Therefore, there are limits to specifying industrial detail in the regional model. At the national level, all economic data are available at four-digit SIC detail for any given industry. In other words, a much more detailed industry study is possible for any specific industry of interest, if a national model was linked to the APCO Economic Model System.

The same situation is true for the availability of the control input data as well. The regional control cost data available in the 305(a) Report of 1970 is the only source of control cost by region for 100 AQCRs and even that is a set of aggregate control costs by region. Only for a limited number of AQCRs control costs at the two-digit detail are available. However, data on control inputs are available for the nation in greater specificity. Utilization of such information will strengthen the understanding of the economic impact of air pollution control strategies.

## 4.5 Alternative Approaches to National Effects Assessment

If it is granted that evaluation of the economics of alternative national strategies is desirable and that an economic model is a useful tool for such evaluation, it remains to consider the different kinds of models which might fulfill this need. CONSAD has identified three broad modelling alternatives to capture in varying degrees the alternatives described in the previous section.

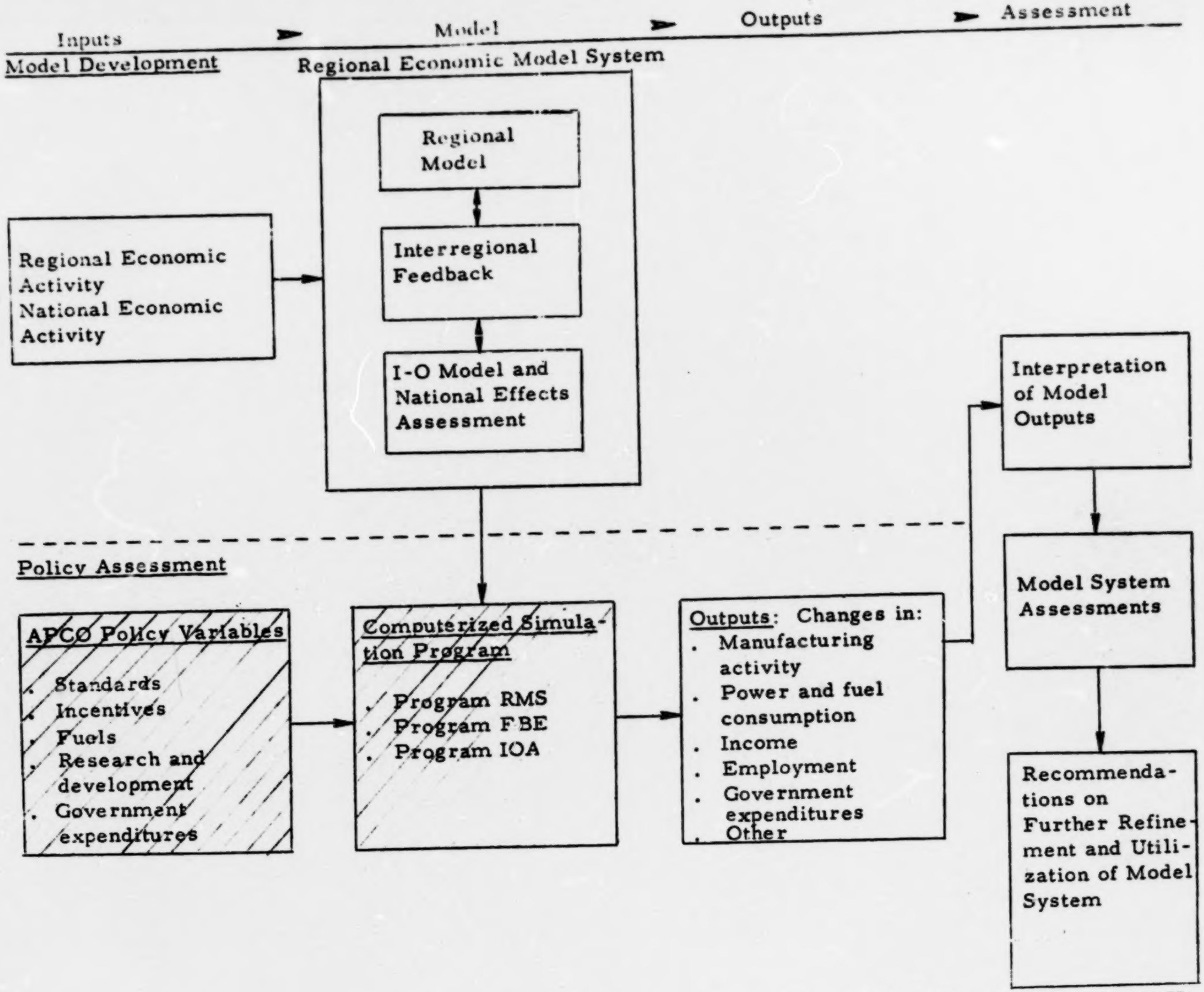
1. One alternative would be to expand the geographic scope of the current Regional Model System to include the remaining AQCRs in the nation. In the process, the model structure may be refined as appropriate.

2. An existing national economic model (e.g., Klein-Goldberger) may be modified and adopted for purposes of strategy assessment.

3. **A new model could be built expressly for the purpose of assessing national effects of Congressionally mandated responsibilities of APCO.**

**For reasons which are best left to the last chapter, CONSAD believes an effort which takes, in part, all three approaches is advisable.**

**CONSAD also believes such a national model is feasible on the basis of preliminary work on formulation of such a model.**


Inputs
Model
Outputs
Assessment
Model Development
Regional Economic Model System
Regional Economic Activity
National Economic Activity
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Policy Assessment
APCO Policy Variables
. Standards
. Incentives
. Fuels
. Research and development
. Government expenditures
Computerized Simulation Program
. Program RMS
. Program FBE
. Program IOA
Outputs: Changes in:
. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other
Interpretation of Model Outputs
Model System Assessments
Recommendations on Further Refinement and Utilization of Model System

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# 5.0 SIMULATING THE IMPACT OF AIR POLLUTION CONTROL STRATEGIES: A SIMULATION OF THREE STRATEGIES

## 5.1 Introduction

The raison d'etre of any economic model is to facilitate accurate and comprehensive prediction of the consequences of changes in particular variables and parameters under the control of policy-makers. The adequacy of predictions so made depends not only on the adequacy of the model itself, but also on the proficiency of the model-user in translating the changes in policy variables he wishes to investigate into appropriate changes in variables and parameters of the model. The computerized economic simulation model does not supplant the expert, but rather, follows through difficult but routine complex logic and calculations, thus freeing the expert for the more creative and demanding task of using the model intelligently.

This chapter of the report is intended to explore the simulation potential of the Regional Economic Model System in the following order.

- First, it describes the range of air pollution control policies for which the model is developed and how these policies need to be translated into appropriate variables of the model before they are introduced into the simulation. An outline of the way the Regional Economic Model System transforms control policy inputs into various model outputs of interest to policy assessment is also provided.

- Second, it describes the implications of the three strategies prescribed by APCO staff for the excercise of the model.

- Third, the chapter outlines the manner in which the three strategies are prepared as inputs for the simulation run and the nature of the outputs of the simulation.

## 5.2 The Scope and Nature of Simulation of the Regional Model

### 5.2.1 Nature of Simulation in General

An economic model purports to describe the relationships between a set of variables of interest in some context, most though not all of which are economic variables. Variables are typically classified dichotomously as either exogenous or endogenous, paralleling the engineer's classification of variables as either input variables or output variables. Exogenous variables are variables not determined by the model, but variables whose values influence the values taken by variables determined by the model. The latter type of variable is called an endogenous variable. For instance, in a model of the wheat market, the average annual price of wheat and annual output would be endogenous variables, while weather indicators, since the weather is not significantly (if at all) influenced by wheat prices and output, are exogenous variables.

Model variables are related to one another in a system of simultaneous equations which system actually comprises the model. The parameters (or coefficients) which appear in these equations are called the structural parameters of the model. They are hopefully stable constants which characterize relatively invariant relationships among model variables. The model is either linear or non-linear depending upon whether all its equations are linear or not.

These concepts may perhaps be clarified by consideration of an actual representation of a model. Ley Y be an $nx1$ vector, the components of which are values of variables endogenous to some model and let Z be an $rx1$ vector of values of variables exogenous or lagged endogenous to some model. Then the notion that Y and Z are linearly related can be represented as:

$$(1) \qquad A\,Y + B\,Z = 0$$

where A and B are respectively $nxn$ and $nxr$ matrices of structural parameters.

A simulation is really nothing more nor less than solving of the model for the endogenous variables given values of the structural parameters and the exogenous variables. The process is particularly simple where the model is linear, as is that outlined above in equation (1). In this common case, the model solution may be obtained explicitly as:

(2) $$Y = -A^{-1} B Z$$

Where the model is non-linear, more complicated techniques for solving systems of non-linear equations (e.g., modified Newton) must be invoked.

Simulation of the effect of a policy involves (1) solving the model for no change in policy, (2) translation of the proposed policy into changes in exogenous variables and/or structural parameters, and (3) solving the model for these changed values. Comparison of the solution values with and without the policy demonstrates the effect of the policy. Steps 1 and 3 are computerized and are thus trivially simple. Step 2, however, demands thorough familiarity with the model, patience, and sometimes considerable ingenuity. Because Step 2 is essentially an endeavor of skillful and critical decision in the absence of all but the most general guidelines, it is best mastered by example and practice. And that is the purpose of the following sections of this chapter.

### 5.2.2 APCO Strategies and the Regional Model

The purpose of this section is to review the range of policies at the disposal of APCO and how they should be transferred for simulation through the model system.

There is a variety of tools available to APCO to meet its Congressionally mandated responsibilities to improve air quality. Under current and foreseeable law, APCO has, as indicated earlier, policy or advisory responsibilities in the following areas:

1. Setting of standards (air quality, emission)
    a. For stationary sources
    b. For mobile sources
2. Incentive policies
    a. Environmental subsidies
    b. Environmental degradation taxes
    c. Accelerated depreciation
    d. Low interest loans
3. Government expenditures
4. Research and development
5. Fuel regulation

The Regional Economic Model System can trace a significant portion of these effects, say when standards set by APCO are used in a simulation of the model. The standards assumed in the 305(a) Report to the Congress are an illustration of such standards.

However, before the 305(a) standards can be used in the simulation, they need to be translated into model variables or model inputs. In other words, the 305(a) standards must be translated into model inputs reflecting these standards, suitable to the model logic, before their effects can be simulated. The 305(a) standards are also expressable in terms of the control costs incident to the high emission industries in the AQCR and are entered into the model as control costs.

These control costs are distinguishable into annualized investment costs and operating costs and are fed into the appropriate component of the model (see Figure 5. 1).

Figure 5. 1 provides an illustrative translation of the various APC policies into appropriate inputs into the model. The model inputs into which APC policies are translatable are of two kinds:

- Changes in exogenous variables of the model, e. g., control costs, damage functions, etc. These are represented by the rectangles in Figure 5. 1.
- Changes in structural-parameter (changes in behavior patterns in the economy), e. g., modified consumption patterns, modified tax structure and changes in the production process; represented by the diamonds in Figure 5. 1

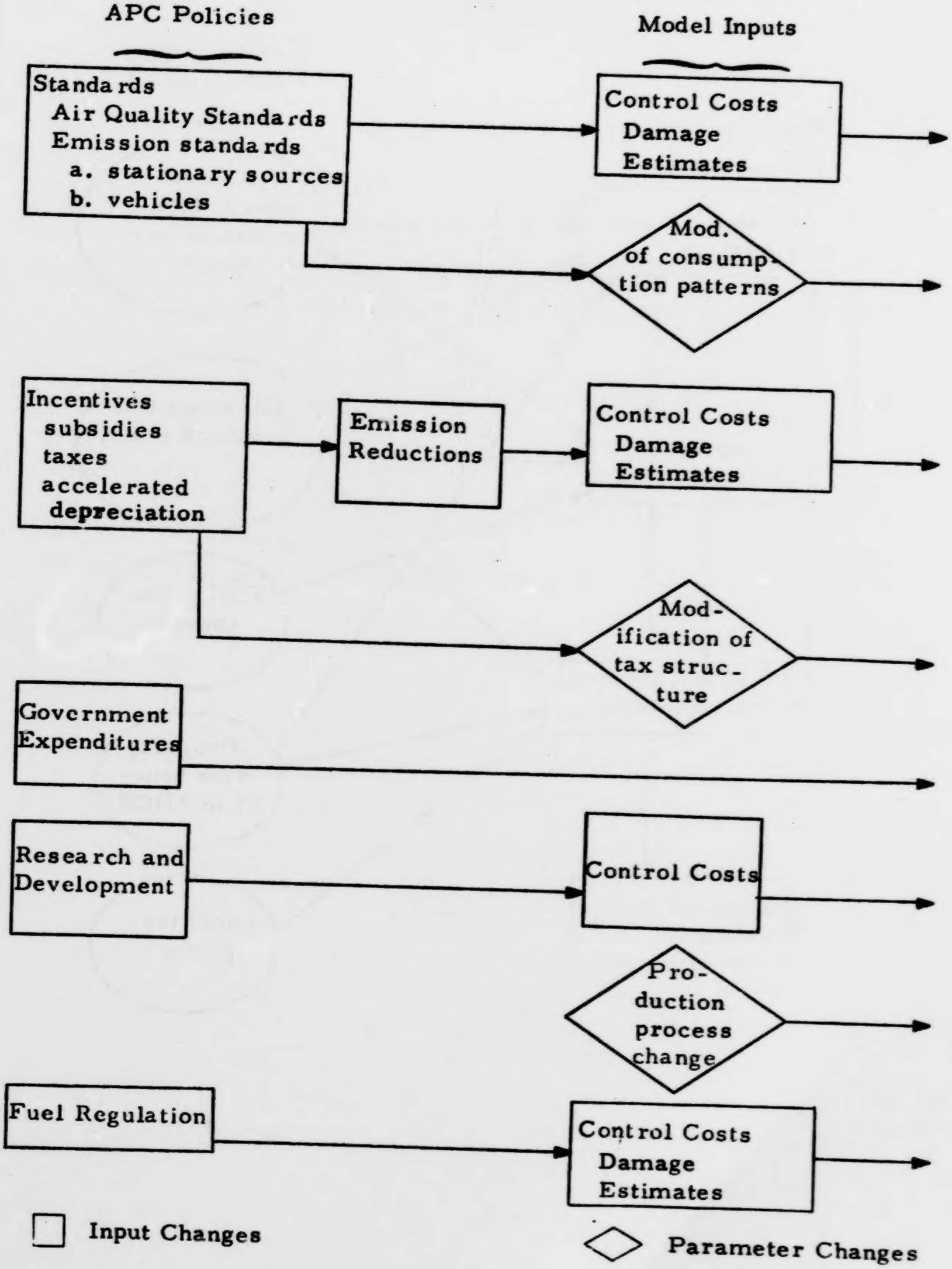
The first step, therefore, in simulation is to identify the model inputs in which form the control policies can be expressed.

### 5. 2. 3 Regional Model System and Control Inputs

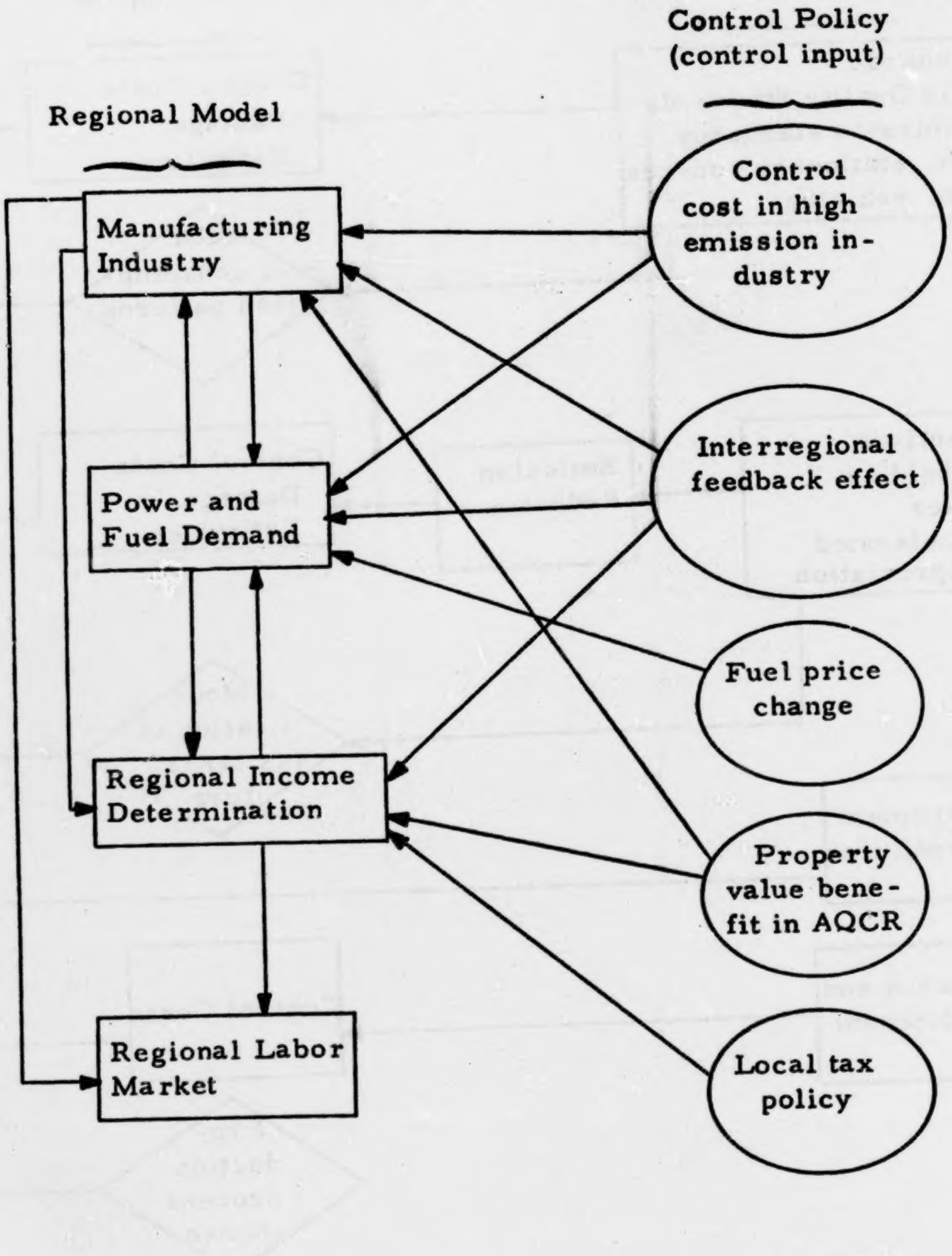
The scope of this section is to illustrate how the various control inputs into the model relate to various components of the model. Such an understanding is vital to effective use of the model.

Figure 5. 2 identifies the four major modules of the Regional Model and identifies their relationships to five types of control policy model inputs.

FIGURE 5.1
APC POLICIES AND MODEL INPUTS


APC Policies
Model Inputs
Standards
Air Quality Standards
Emission standards
a. stationary sources
b. vehicles
Control Costs
Damage
Estimates
Mod. of consumption patterns
Incentives
subsidies
taxes
accelerated
depreciation
Emission Reductions
Control Costs
Damage
Estimates
Modification of tax structure
Government Expenditures
Research and Development
Control Costs
Production process change
Fuel Regulation
Control Costs
Damage
Estimates
Input Changes
Parameter Changes

## FIGURE 5.2
## REGIONAL MODEL AND CONTROL INPUTS


Control Policy (control input)
Regional Model
Manufacturing Industry
Power and Fuel Demand
Regional Income Determination
Regional Labor Market
Control cost in high emission industry
Interregional feedback effect
Fuel price change
Property value benefit in AQCR
Local tax policy

The control cost to the high emission industries associated with a given emission or air quality standard will lead to a cost increase in those industries and power industries in particular. These cost increases will enter into the manufacturing industry module (in the investment and profit components) and the fuel demand module (price of electricity equations) and will cause changes in the output of manufacturing industries. Changes in the production will affect the fuel demand of the industries and affect the regional income and regional labor market.

Interregional feedback effect, from the benefits to be realized from cleaner air is brought to the regional model from a national I-O model. This feedback effect can also feed in price changes of products, increased demand for control equipment, etc., through the link it provides between the regional model and the national I-O system. Fuel price changes will affect the fuel substitution in the regional model and relate to the other parts of the model. If property value benefits by AQCR can be estimated, net increase of disposable income, will augment additional local consumption expenditures. An increase of the productivity attendant on pollution abatement can lead to an increase in the profit. Finally, if any local taxes are introduced to aid the implementation of air pollution abatement, its impacts on the regional economy can be traced.

Figure 5.3 provides a more detailed look at the way control inputs course through the model.

A simulation program consisting of the following three major modules has been prepared:

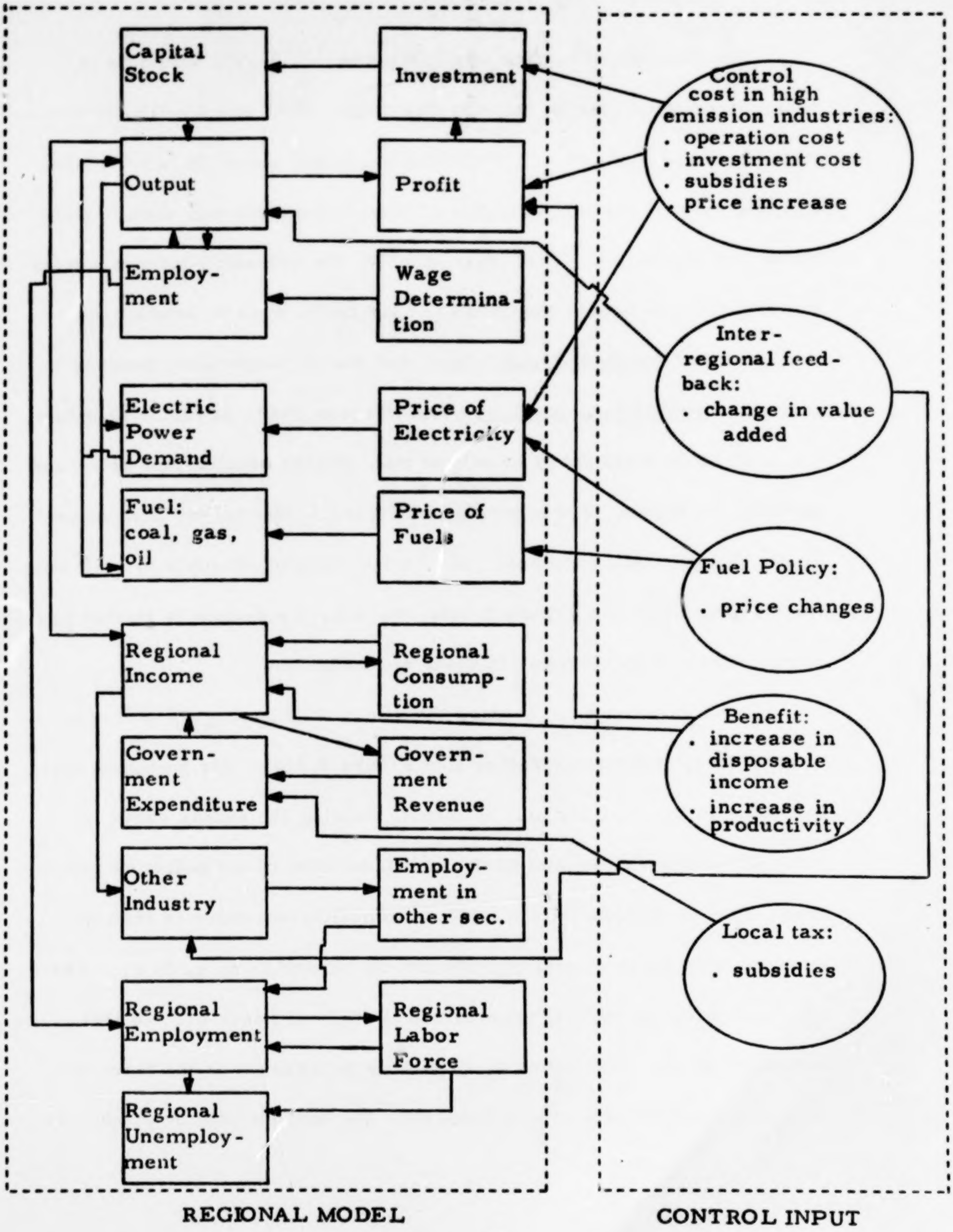
. RMS (Regional Model),
. IOA (Input-Output Model), and
. FBE (Interregional Feedback).

A detailed description of the simulation program appears in Volume II. It will be used in the next section to simulate the effects of three strategies specified by APCO staff.

## 5.3 Simulating Three Strategies: The Definition of Strategies

APCO specified three strategies to be simulated by the model. All three of the simulations to be discussed here have as their basis the control costs envisioned in the 1970 Report to Congress as required by Section 305(a) of the Clean Air Act of 1967. The simulations reflect differing policies and assumptions with respect to the incidence of control cost expenditures -- that is, with respect to who finally pays the cost of controlling air pollution. Before beginning a detailed description and analysis of the strategies studied here, some general comments on incidence and its determinants are in order.

**FIGURE 5.3**
**REGIONAL MODEL AND CONTROL POLICIES: A MORE DETAILED LOOK**


Capital Stock
Investment
Output
Profit
Employment
Wage Determination
Electric Power Demand
Price of Electricity
Fuel: coal, gas, oil
Price of Fuels
Regional Income
Regional Consumption
Government Expenditure
Government Revenue
Other Industry
Employment in other sec.
Regional Employment
Regional Labor Force
Regional Unemployment
Control cost in high emission industries:
. operation cost
. investment cost
. subsidies
. price increase
Inter-regional feedback:
. change in value added
Fuel Policy:
. price changes
Benefit:
. increase in disposable income
. increase in productivity
Local tax:
. subsidies
REGIONAL MODEL
CONTROL INPUT

The diagram presented in Figure 5.4 is a supply schedule (a schedule relating market price to quantities which suppliers will wish to produce and sell per unit time) and a demand schedule (a schedule relating market price to quantities which consumers will wish to purchase per unit time). That price at which the quantity consumers wish to purchase just equals the quantities suppliers wish to produce and sell is called the equilibrium price, and the corresponding quantity is called the equilibrium quantity. The effect of shifts in either schedule, i.e., shifts in willingness to sell or buy, causes equilibrium price and quantity to change. For example, in Figure 5.5(a) below, consumers' disposable income increases, causing the demand schedule to shift outward to the right. In Figure 5.5(b), the supply schedule is shifted upward reflecting an increase in costs of production.

In simple graphical terms, the effect of imposing air pollution control on an industry is rather like Figure 5.5(b). Air pollution control adds to the cost per unit of output, causing the supply curve to shift upward by the amount of the additional cost of air pollution control. This is depicted in Figure 5.6. Equilibrium price is then increased from $p_o$ to $p_1$ and equilibrium decreased from $q_o$ to $q_1$. The total air pollution control expenditure is $(p_1 - a)$ times $q_1$. Of this total amount $(p_1 - p_o)$ times $q_1$ is paid by purchasers in the form of higher prices for each unit purchased. The amount paid by producers

FIGURE 5.4
SUPPLY SCHEDULE

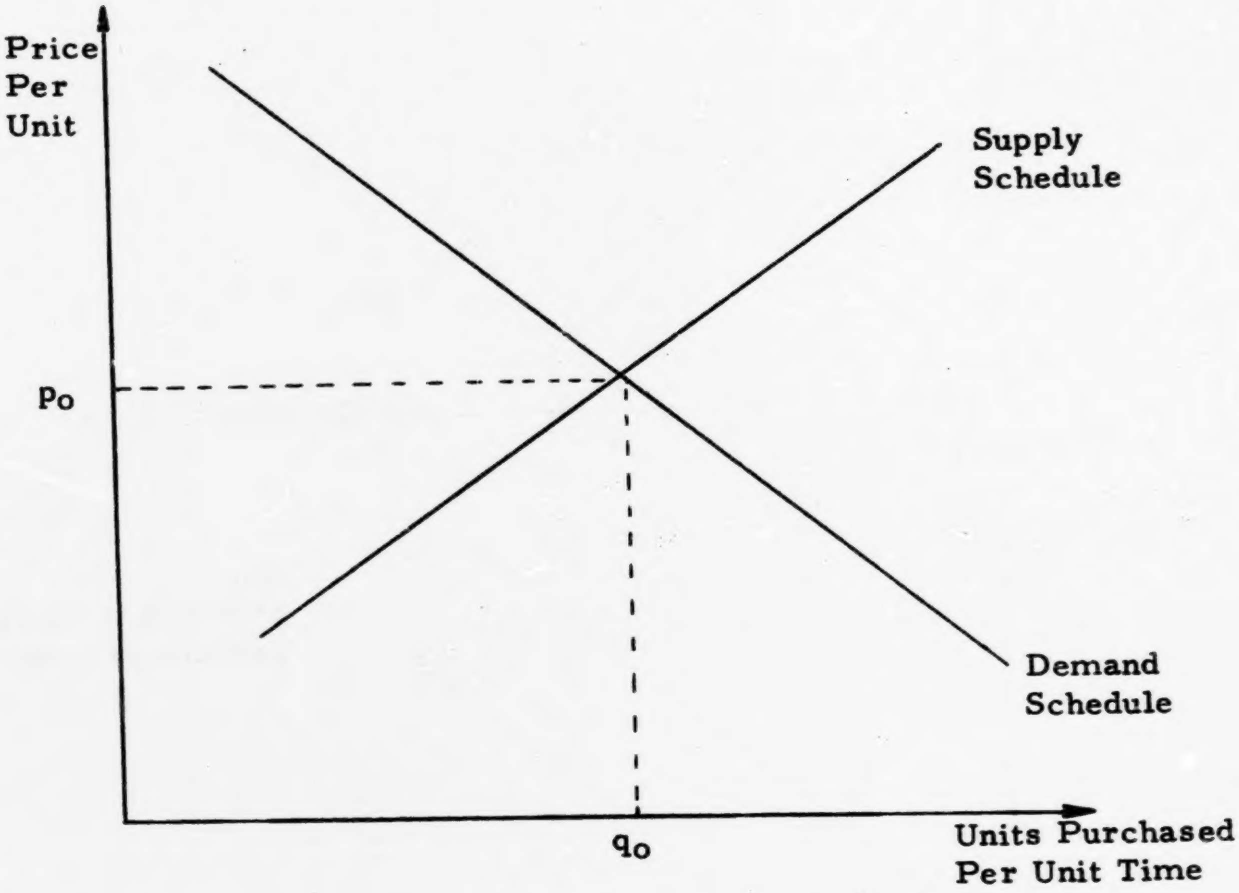
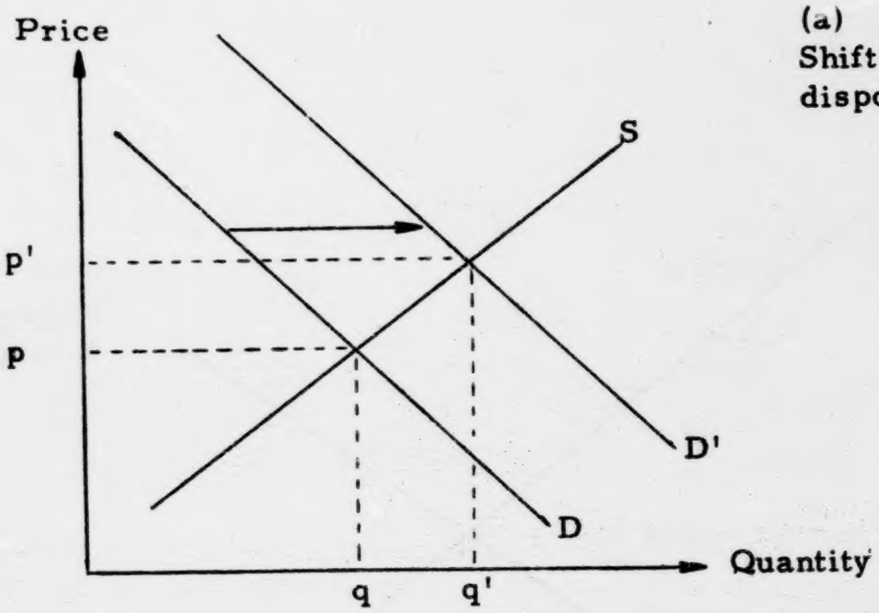
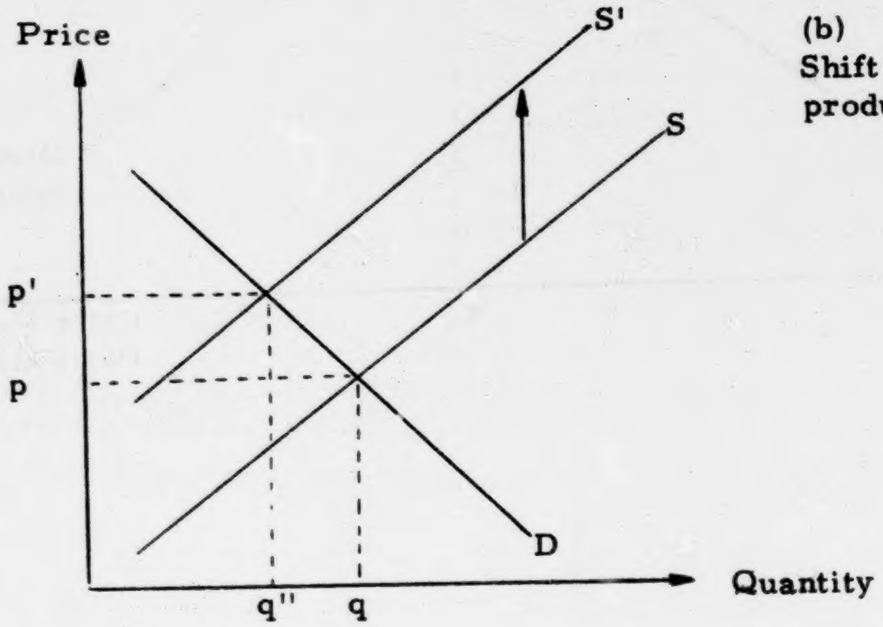


FIGURE 5. 5



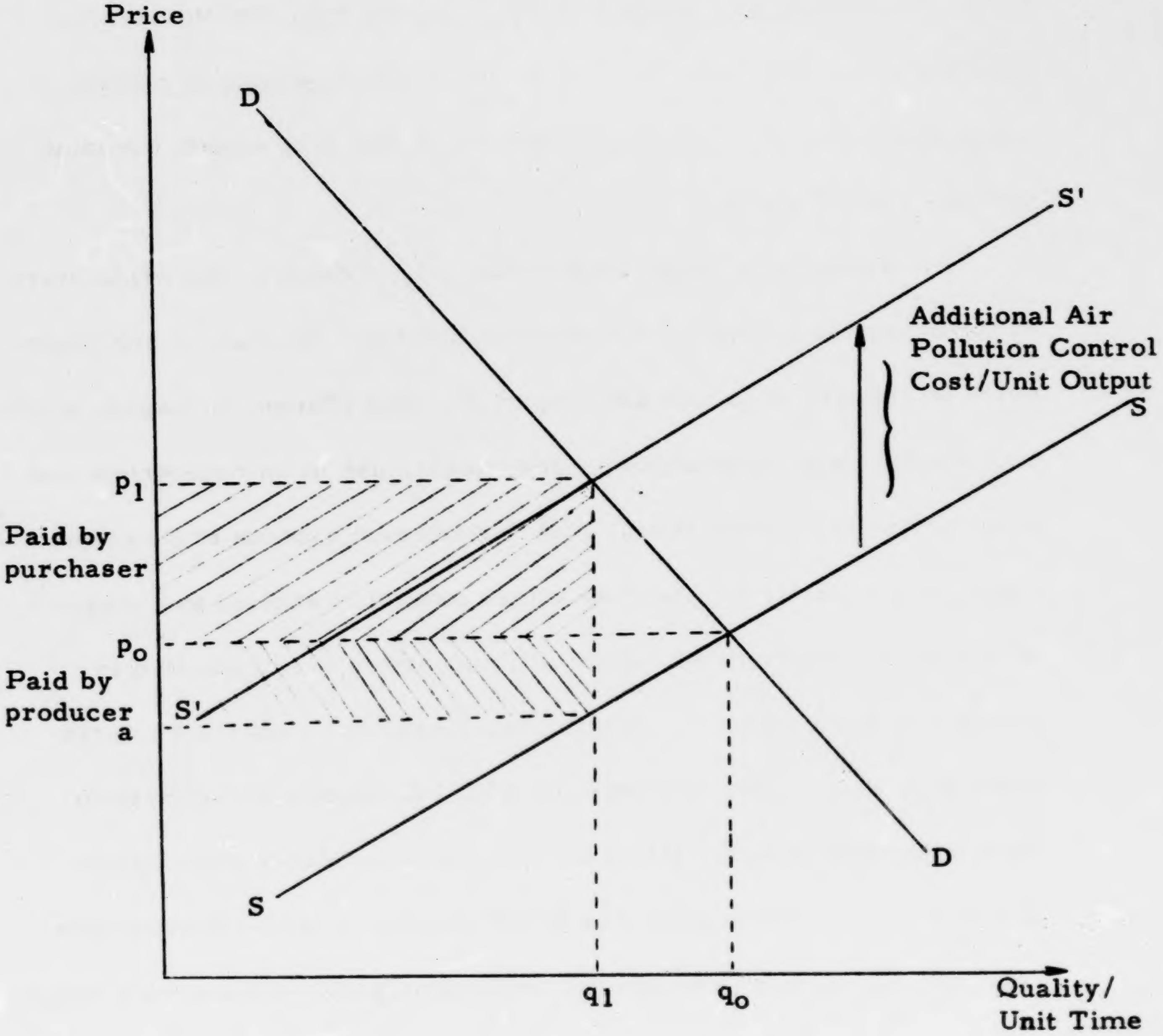
(a)
Shift due to increase in disposable income



(b)
Shift due to increase in production costs

FIGURE 5.6

AIR POLLUTION CONTROL COST PER UNIT OUTPUT



in the form of lower revenues net of control costs is given by $(p_o - a)$ times $q_1$. The difference in prices paid by consumers, $(p_1 - p_o)$ is called the incidence of control costs on consumers, and the complementary price difference $(p_o - a)$ is called the incidence of control costs on producers. The sum of the incidences thus equals the total per unit cost of control.

Incidence for a single industry is not, of course, the whole story of the economic impact of air pollution control. Not only is one interested in changes in prices and output, but also changes in wages, profits, employment, consumption, investment, use of raw materials and other artifacts of production. And this interest extends to those quantities not primarily for the case where control is applied to a single industry, but where most, if not all, industries are controlled in greater or lesser degree. There are, therefore, important interindustrial effects. This is where the APCO Economic Model System makes its contribution. Using the results of incidence calculations and other input information, the APCO Economic Model System forecasts the consequences of alternative control policies for a wide range of economic variables, taking into account interindustrial effects.

The three strategies selected by APCO for simulation and analysis in this report differ from one another in the kind and degree of governmental intervention to shift the incidence of air pollution control costs.

A general description of the three strategies follow.

Strategy 1: Industry Pays

There are some who contend that industry should bear the full cost of controlling air pollution; that is, that the incidence of control costs on consumers or government should be zero. The argument buttressing this policy position is a moral one (as are those which lie behind other policy positions) and is thus beyond the purview of scientific enquiry. The concern here is solely with discovery of the probable effects of such a policy if it were pursued.

The most plausible specific policy which the government could use to insure that industry alone bears the incidence of air pollution control costs is to freeze prices at their level prior to instituting air pollution control. This effectively produces a kinked demand curve, perfectly elastic, at quantities less than that which was obtained before air pollution control. This is diagrammed in Figure 5.7. Since the effect air pollution control is to shift the supply curve upward, the new equilibrium price and quantity will fall along the perfectly elastic portion of the demand curve. Remembering that where demand is perfectly elastic, the full burden of air pollution control costs falls on the supplier, it is demonstrated that price freezes coupled with air pollution control will achieve the distribution of incidence desired under Strategy 1. This approach is diagrammed in Figure 5.8.

FIGURE 5.7

PRICE FREEZE DEMAND SCHEDULE

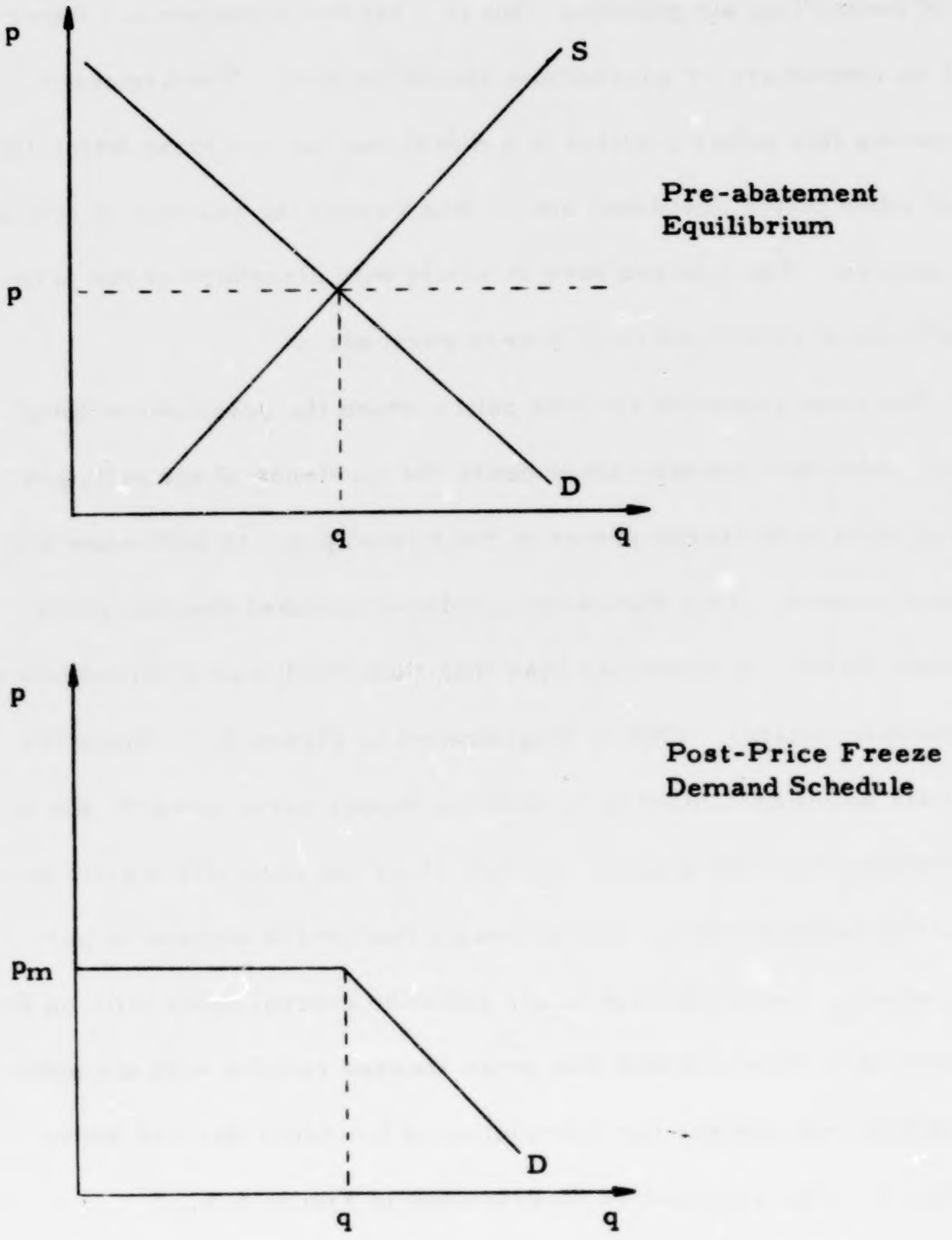
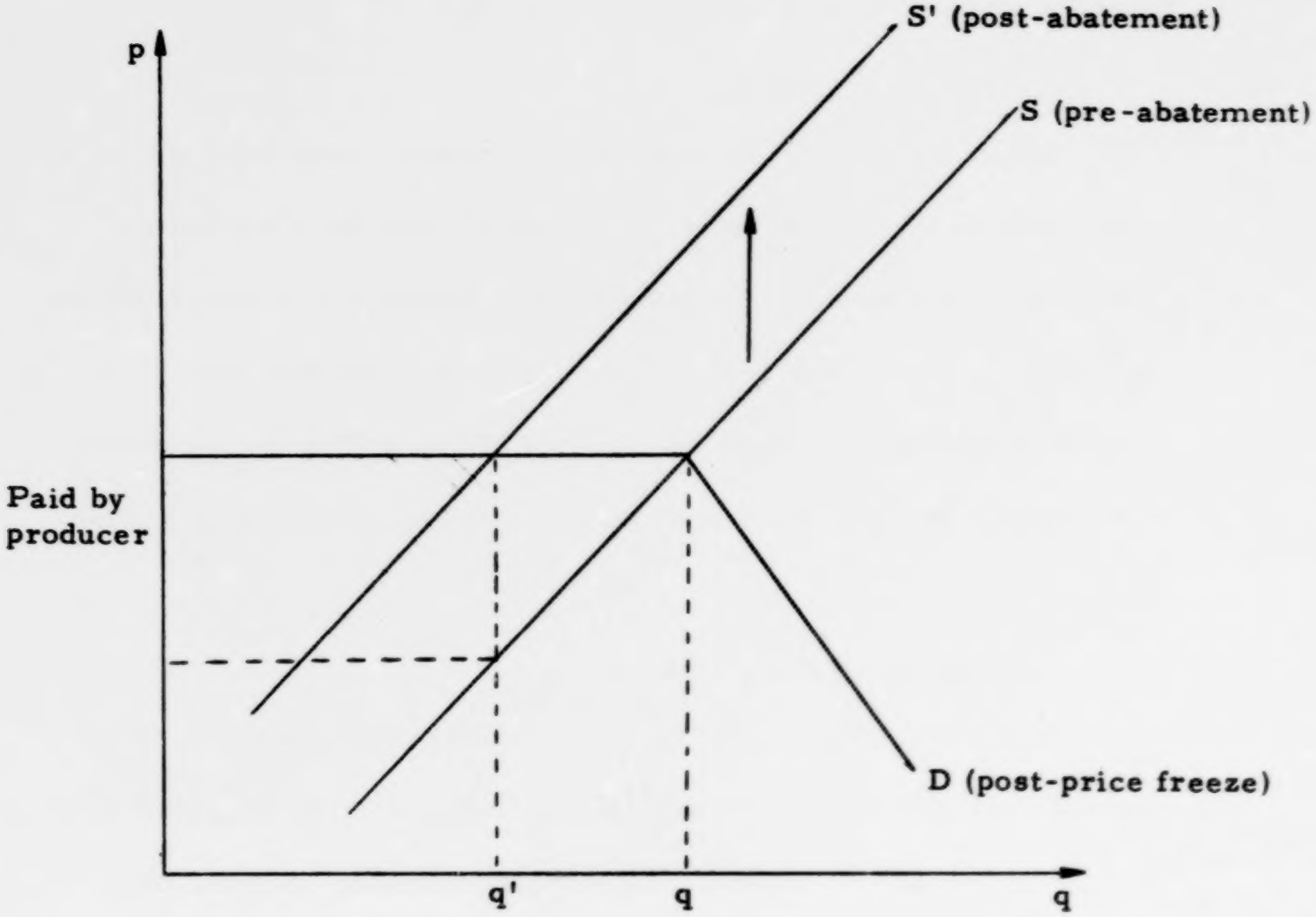


FIGURE 5. 8

DEMAND AND SUPPLY RELATIONS UNDER STRATEGY 1



It is assumed that Strategy 1 differentiates between public utilities and other industries, allowing the former to pass along in toto the additional cost of control so as not to jeopardize the already supposedly minimal rate of return in this sector.

Strategy 2: Hands Off

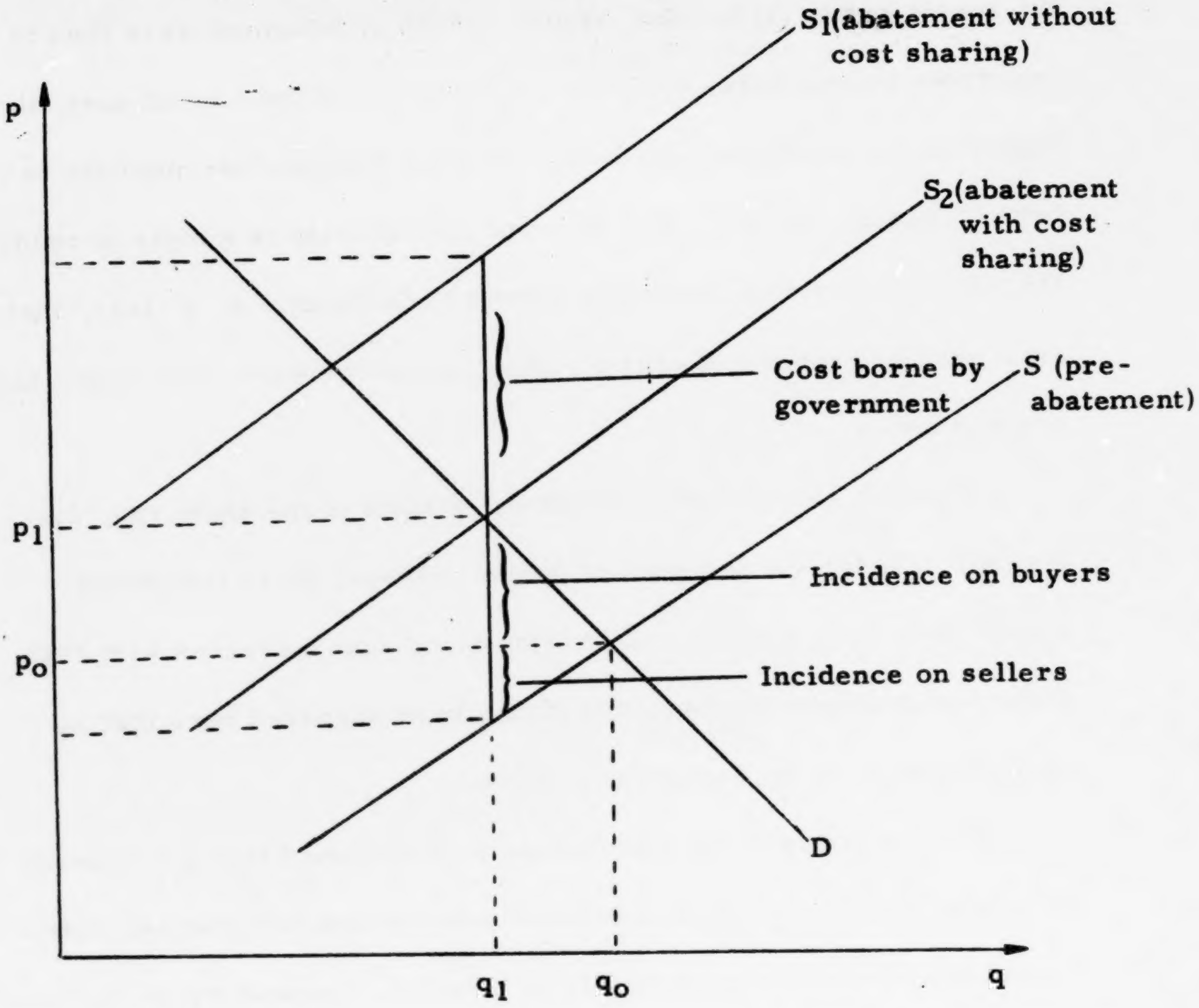
Under Strategy 2, the incidence of control costs falls where it may, with no attempt by the government to alter the distribution achieved by the market. In other words, Strategy 2 is simply an air pollution control policy with no accompanying economic policy. In diagrammatic terms, the consequences of this policy for incidence and changes in price and output may be seen by referring to Figure 5.6.

Strategy 3: Cost Sharing

It is frequently argued that if government shares some of the cost of control which would normally fall on industry, undesirable economic effects of control would be much attenuated. In particular, the net result of cost sharing, it is argued, would be to reduce the amount by which prices will rise and output will fall. The reasoning behind this argument is presented diagrammatically in Figure 5.9. As shown earlier, the immediate effect of air pollution control is to shift the supply curve upward by the amount of the additional cost of air pollution control. Producers are willing to produce and sell only if they

FIGURE 5.9

DEMAND AND SUPPLY RELATIONS UNDER STRATEGY 3



are able to cover all costs of so doing. Hence, without cost sharing, the supply curve shifts from S to S'. If the government were then to undertake to reimburse industry for a portion of the control cost, the supply curve would shift downward to some position intermediate between S and S', say S''. The effect of cost sharing is simply to reduce the additional cost of control as viewed by industry. It is clear, that as argued by proponents of this policy, price increases and output falls are attenuated.

Because elasticities of demand, at least in the short run, are typically low for the services of public utilities, these industries should have little difficulty in passing along cost increases with little reduction in output. It has, therefore, been supposed here that no cost sharing is to be done with utilities.

For purposes of the simulation, it is assumed that government is to bear 50 percent of all industrial process and combustion control costs, which would otherwise fall on industry, financed by an increase in Federal personal income taxes, and no portion of other control costs as indicated above.

### 5.4 Preparing Inputs for Simulation

The difficult task remains of translating each of these three strategies into values of exogenous variables and parameters in the

APCO Economic Model System so that simulation can be executed. The process by which this is done is described in the text and figures of the following pages.

The raw data on which simulations with the APCO Economic Model System rest are (1) control costs by AQCR (and by 2-digit SIC if available) for industrial processes and combustion, (2) control costs for steam electric power generation, and (3) benefits which will occur because of air pollution control outlays. Data on items (1) and (2), for the simulations reported here, were taken from the 1970 Report to the Congress required by Section 305(a) of the Air Quality Act of 1967. For purposes of benefit determination as required under item (3), the conservative estimate is that air pollution causes $10 billion worth of damage annually. These data, however, form only the basis for simulation. The model user must still exercise considerable judgment in deciding precisely how they shall be used in the simulation.

To fully understand the simulation process for this model, however, one must delve yet deeper into its inner workings. Appendices C, D and Volume II provides such a detailed review of these details.

With this rather detailed background in mind, it is time to discuss conversion of raw data into model inputs. Benefits are discussed first since the treatment of benefits is precisely the same under the three strategies. A conservative total damage figure of $10 billion* is assumed, and it is assumed that roughly a 20 percent reduction in annual damages would occur if the control costs programmed in the 1970 Report to the Congress under Section 305(a) of the Air Quality Act of 1967 were incurred. An annual damage reduction of $2 billion is thus implied. This annual damage reduction is treated as an increase in consumers' disposable income, which treatment implies an increase in consumption, assuming a marginal propensity to consume 0.8, of $1.6 billion. This increase in consumption was treated as an increase in final demand in the Interregional Feedback Submodel, distributed among the various sectors in that model according to the historical distribution of consumption in each of the feedback models' sectors.

All the raw cost of control information was taken from the 1970 305(a) Report. These costs reflect the following emission reductions of particulates, sulfur oxides, hydro carbons and carbon monoxides in the 100 AQCRs:

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*U. S. Department of Health, Education and Welfare, National Air Pollution Congrol Administration, Costs and Economic Impacts of Air Pollution Control, Fiscal Years 1970-1974, January, 1969, p. iv.

| Pollutant | Source Category | Emission Decrease (%) |
|---|---|---|
| Particulates | Solid waste | 77.8 |
| | Stationary combustion | 91.7 |
| | Industrial process | 86.1 |
| Sulfur oxides | Stationary combustion | 52.2 |
| | Industrial process | 36.2 |
| Hydrocarbon | Solid waste | 69.4 |
| | Industrial process | 57.8 |
| Carbon monoxide | Solid waste | 84.7 |
| | Industrial process | 90.2 |

The only difference between the three strategies is in the treatment of control cost, which treatment reflects, as noted above, differing policies with respect to who shall bear the cost of control. Under Strategy 1 (Industry Pays), the full burden of industrial control costs and increased costs of electric power used by the manufacturing and non-manufacturing sector falls upon industry. Consumers pay only the increased cost of the electric power they use.

For each AQCR, control costs can be identified in three categories, namely, investment expenditures on control equipment, annual operation cost, and control cost of electric power industry.* By notation:

---

*Aggregation of the five-year average control cost over 91 AQCRs under the present study is $1, 333 million. Unfortunately, control costs by AQCR are not available on 2-digit SIC breakdown, although the present model can use such data. A separate simulation run, based on 2-digit SIC detail control costs for St. Louis, Cincinnati, and Washington, D.C. AQCR, has been conducted.

$$\Delta C_i = \Delta C_{i1} + \Delta C_{i2} \qquad i = 1, \ldots, 91$$

where $\Delta C_i$ is the total control cost of manufacturing industry in $i^{th}$ AQCR,

$\Delta C_{i1}$ is the investment expenditure of control in $i^{th}$ AQCR,

$\Delta C_{i2}$ is the annual operational cost of control in $i^{th}$ AQCR.

It has been assumed that electric power industry will pass on the entire control cost to the users by a price increase of:

$$\Delta_{qi} = \frac{O_i}{Q_i}$$

where $\Delta_{qi}$ price increase of electricity in $i^{th}$ AQCR,

$O_i$ control cost of electric power industry in $i^{th}$ AQCR,

$Q_i$ total regional consumption of electricity in $i^{th}$ AQCR.

Under Strategy 1 (Industry Pays), annual operation cost $\Delta C_{i2}$ has been reduced from the gross profit $(\sum_j \Pi_{ij})$ of the manufacturing industry, and the investment expenditure $\Delta C_{i1}$ from the gross investment $(\sum_j I_{ij})$ in each AQCR. On the other hand, control cost to the electric power industry becomes a price increase of electricity and passed on to three types of users:

| | |
|---|---|
| Control cost passed to manufacturing industry | $\Delta q_i \cdot \sum_j Q_{ij}$ |
| Control cost passed to the AQCR residents | $\Delta q_i \cdot Q_{ci}$ |
| Control cost passed to the other industries | $\Delta q_i \cdot \overline{Q_i}$ |

where $Q_{ij}$ is electricity used by jth industry in ith AQCR. Therefore, $\Delta q_i \sum_j Q_{ij}$ becomes further reduction to the gross profit from manufacturing industry in each AQCR. $Q_{ci}$ is the electricity consumed by residence of ith AQCR, hence, $\Delta q_i\ Q_{ci}$ is a reduction on the regional disposable income ($Y_i$). Finally, $\Delta qi\ \overline{Q}_i$ is passed to the other industries.

The benefits from control (i.e., $1.6 billion additional consumption as the total benefit in the nation) was distributed to corresponding sectors of the nation based on the average propensity to consumers by sectors.* By use of the national I-O model (Program IOA) direct and indirect increase of production (value of shipment) by sector were estimated and then, by use of regional market share matrix (Program FBE), the impact of benefit at the national level is distributed to each AQCR.

Under Strategy 2 (Hands Off), a part of the control cost is passed on as price increase. A prior estimation of price increase by industry was reported by the 305(a) Report of 1971. In this study, a weighted average price increase of 0.4 percent for manufacturing industries was derived.* Therefore, under Strategy 2, the control cost to the manufacturing industries becomes:

---

*See Appendix D for percentage distributions among consumption items and regional market share matrix.

$$\Delta C_i^* = \Delta C_i - \Delta P_i$$

$$\Delta P_i = r \cdot \sum_j V_{ij}$$

r is percentage price increase and $\sum_j V_{ij}$ is total production (value-added) of manufacturing industries. Hence, $\Delta P_i$ is the part of control cost passed on to the consumer by price increase which reduces $\Delta C_1$ and $\Delta C_2$ proportionally, although the price increase in electricity remains the same as before. On the other hand, the price increase of the manufacturing product in the nation will result in an inflationary effect on disposable income, which will be reduced by the same amount. It is estimated that $624 million out of $1,333 million control cost has been passed on the consumer by the price increase. This reduction of the disposable income in the nation is distributed to each AQCR in the same manner as benefit.

---

*In a recent study of the price increase among high emission industries, it is shown that the percentage price increase among different products depends upon the price elasticity of the corresponding product. An 0.4 percent "average" price increase for manufacturing industries was derived from the weighted average of the percentage price increase by two- to three-digit SIC industries weighted by the corresponding volume of sales by each industry. Data used in this calculation is obtained from LeSourd, D. A., et al., Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Effects of Air Quality Standards, Research Triangle Institute, December, 1970.

Under Strategy 3 (Cost Sharing), it has been assumed that the Federal government will subsidize 50 percent of the remaining control cost which industry cannot pass on by price increase. Therefore, the control cost of the manufacturing industries become:

$$\Delta C_i^{**} = \Delta C_i - \Delta P_i - \Delta F_i$$

$$\Delta F_i = \frac{1}{2} (\Delta C_i - \Delta P_i)$$

The government subsidy of $\Delta F_i$ is 50 percent of the remaining control cost to the manufacturing industries. This again is proportionally reduced from $\Delta C_{i1}$ and $\Delta C_{i2}$. On the other hand, it is assumed that the Federal government will raise the same amount of tax from the public. An estimated amount of $355 million reduction of disposable income in the nation was assumed. The impact on each AQCR is also treated through the I-O model and regional market share matrix as before (see Table 5. 1).

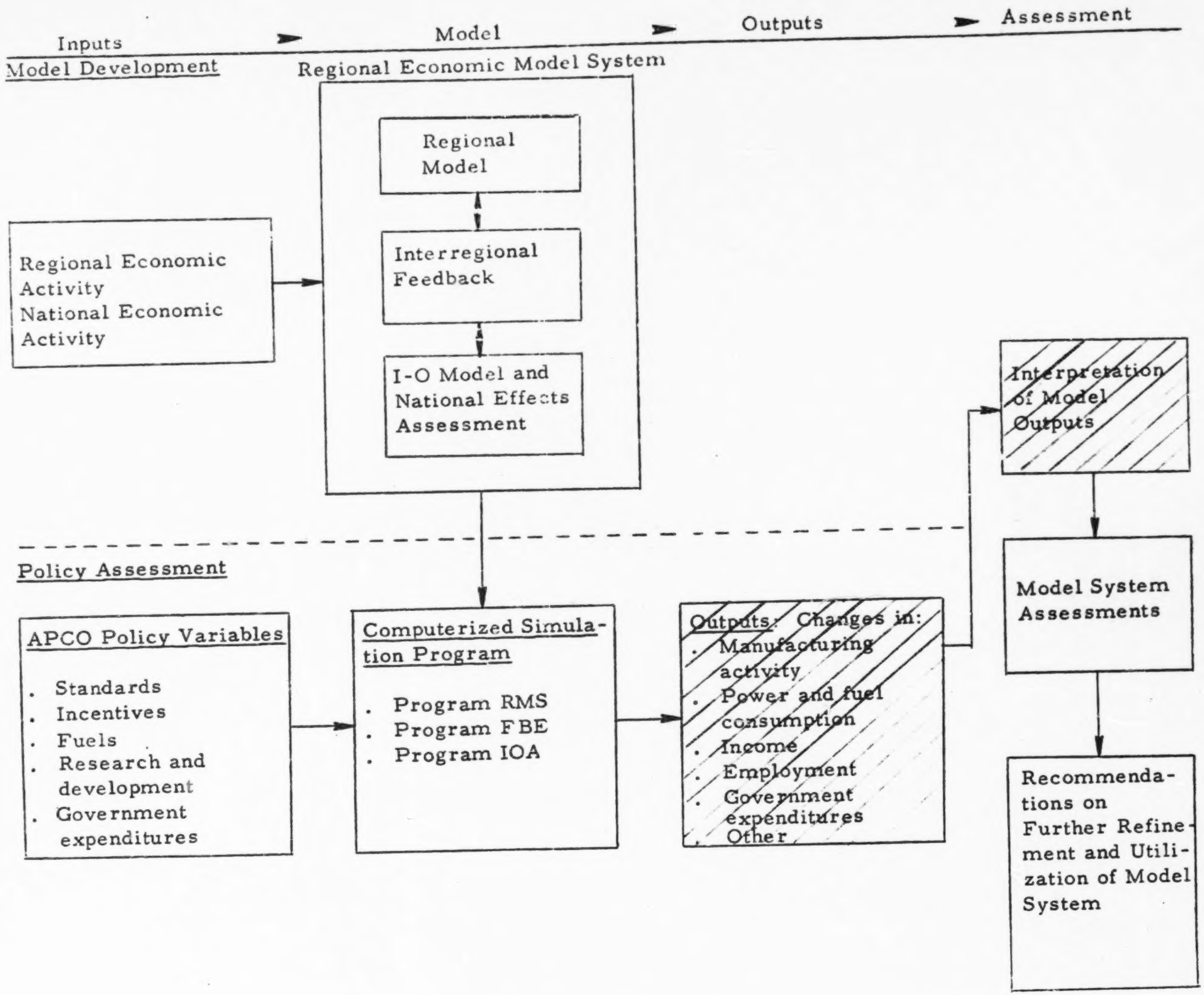
The results of the simulation of the three strategies are presented and interpreted in the next chapter.

## TABLE 5.1

## INCIDENCE OF CONTROL COSTS UNDER THE THREE STRATEGIES (in millions)*

| Strategy | Cost Incurred By | | | Total |
|---|---|---|---|---|
| | Manufacturing Industry | Consumers | Government | |
| 1 | $1333 | -- | -- | $1333 |
| 2 | $ 709 | $ 624 | -- | $1333 |
| 3 | $ 354 | $ 629 | $ 355 | $1333 |

*In Strategy 1, high emission industries are assumed to absorb the entire cost of control. In Strategy 2, high emission industries will pass on part of the control costs as a 0.4 percent price increase to the consumer. In Strategy 3, it is assumed that the Federal government will raise, by a special tax to subsidize the high emission industries by an amount equal to 50 percent of the control costs not covered by the price increase in Strategy 2. In all three strategies, it is further assumed that electric utilities will pass on their control costs to the consumers as a price increase. For a detailed description of the three strategies, see page 94 or Chapter 5.


Inputs
Model
Outputs
Assessment
Model Development
Regional Economic Model System
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Regional Economic Activity
National Economic Activity
Policy Assessment
APCO Policy Variables
. Standards
. Incentives
. Fuels
. Research and development
. Government expenditures
Computerized Simulation Program
. Program RMS
. Program FBE
. Program IOA
Outputs: Changes in:
. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other
Interpretation of Model Outputs
Model System Assessments
Recommendations on Further Refinement and Utilization of Model System

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# 6.0 INTERPRETATION OF THE EFFECTS OF THREE TRIAL STRATEGIES

This chapter is intended to provide a brief interpretation of the preliminary results of the simulation of the three strategies specified by APCO. It opens with a brief recapitulation of the assumptions underlying the three strategies. It proceeds to a brief discussion of the framework of analysis of the model output through a series of questions. Next, it identifies the geographic patterns of incidence of a key economic indicator unemployment rate under the three alternatives. Finally, it explores the patterns of change of two other key indicators -- profits and personal income -- under the three strategies on the 91 AQCRs, and assesses the potentials of the interpretations attempted here.

## 6.1 The Three Strategies

As described in the previous chapter, the three alternative strategies tested with the APCO Economic Model System have as their basis the control costs envisioned in the 1970 Report to Congress as required by Section 305(a) of the Clean Air Act of 1967.* These three strategies are summarized in Figure 6.1.

---

*Hereafter, it will be referred to as the 305(a) Report.

## FIGURE 6.1
## THE THREE STRATEGIES AT A GLANCE

### APC Strategy 1

1. High emission industries will absorb the entire control cost as costs increase in the production without price increase.

2. Electric utilities (SIC 4911) will pass over the control cost to the users as price increases to industries and consumers.

3. The benefits from air pollution control will result in a $1.6 billion increase of consumption in the nation based on average propensity for consumption of goods and services, generating an increase in production of corresponding industries in each AQCR.

### APC Strategy 2

1. High emission industries will increase the price of products as part of control cost increase. It is estimated that $624 million out of a total control cost of $1,333 million will be passed on to the consumer as the result of an average 0.4 percent increase of the manufacturing product price.

2. Because of the price increase in the products of the high emission industries, consumers in the nation will reduce consumption to $623 million.

### APC Strategy 3

1. Besides price increases assumed in the APC Strategy 2, high emission industries will receive 50 percent of Federal government subsidies for the part of control cost which is not passed on by price increases of the products.

2. Federal government will raise an amount of tax equal to the subsidy to the high emission industries; therefore, the national disposable income will be reduced by $355 million, in addition to the price increase on the products of high emission industries.

## 6.2 An Approach to Assessment of Effects of the Three Strategies

For each strategy simulated, the APCO Economic Model System gives a varied and detailed output describing the economic situation in the region with and without the control strategy. For example, Table 6.1 presents the summary table for the New York AQCR under the "Industry Pays" strategy. Evidently, the model produces so great an output that one needs a framework to analyze these outputs and compare the three strategies, otherwise it may be difficult to "see the forest for the trees."

The approach taken here is to pose questions on which the model impinges. The questions to be considered are the following:

- What effect does air pollution control have on the nation's regions?
- How is this effect modified by government strategies for modifying the incidence of control expenditures?
- How are geographical effects modified by government strategies for modifying the incidence of control expenditures?
- Are there any geographical patterns of economic effects of air pollution control?
- If so, what explanations can be advanced for these patterns?
- What changes in the structure of economic activity occur within regions?

```
TOTAL NET EFFECT OF ALL CONTROL STRATEGIES PURSUED IN THIS RUN

AQCR   1    NEW YORK, N.Y.
                                                                WITHOUT       NET        PERCENT
                                                                CONTROL      CHANGE      CHANGE
   MANUFACTURING INDUSTRIES

     PROFIT (MILLIONS)                                          5738.902     -33.051    -0.57591
     INVESTMENT (MILLIONS)                                       452.000     -20.394    -4.51190
     VALUE ADDED (MILLIONS)                                    13836.699       5.273    -0.09929
     CAPITAL STOCK (MILLIONS)                                  10884.758     -19.132    -0.17577
     EMPLOYMENT (1000 S)                                        1144.000      -6.432    -0.56227

   OTHER INDUSTRIES

     EMPLOYMENT (1000 S)                                         3979.71      -2.866    -0.07202

   REGIONAL CONSUMPTION (MILLIONS)                             32445.000     -30.164    -0.09297
   TOTAL PERSONAL INCOME FOR THE REGION (MILLIONS)             53712.000     -41.488    -0.07724
   TOTAL REGIONAL EMPLOYMENT (1000 S)                           5123.711      -9.293    -0.18137
   REGIONAL UNEMPLOYMENT (PERCENT)                                 4.000      0.1741     4.35349
   TOTAL LABOR FORCE (1000 S)                                   5337.199      -9.660    -0.18100
   GOVERNMENT EXPENDITURE FOR THE REGION (MILLIONS)             5944.000      -3.929    -0.06610
   GOVERNMENT REVENUE FROM THE REGION (MILLIONS)                6416.000      -4.165    -0.06491

   ELECTRIC POWER DEMAND

     TOTAL ELECTRIC CONSUMPTION FOR THE REGION (1000  KWS)      4878.000      -6.364    -0.13047
     ELECTRICITY USED BY MANUFACTURING INDUSTRIES (1000 KWH)     518.00       -2.736    -0.52817
     ELECTRICITY USED BY OTHER INDUSTRIES (1000 KWH)            3205.00       -2.205    -0.06881
     RESIDENTIAL CONSUMPTION IN THE REGION (1000  KWH)          1155.000      -1.423    -0.12322
```

TABLE 6.1

SAMPLE OUTPUT OF AN AQCR: A SUMMARY TABLE

- How are these changes moderated by incidence strategies?

The issues raised by these questions are addressed in several steps. First, a key economic indicator -- change in unemployment rate -- is analyzed in the various AQCRs and patterns of change under the alternative strategies are interpreted. Then the consistency of two other key indicators -- profits in manufacturing industries, regional personal income -- with the patterns evidenced in unemployment rate changes is explored. Next, an interpretation of the net effects aggregated over 91 AQCRs as evidenced by these three indicators is attempted. Finally, the potentials of the interpretation of results displayed here are assessed.

## 6.3 Changes in Unemployment Rates Under the Three Strategies

A key economic indicator, change in regional unemployment rate attendant on the three alternative air pollution control strategies, is analyzed here.

Table 6.2 shows the change of unemployment rate in each AQCR from the simulation outputs of the three alternative APC strategies.

If one compares the change of unemployment rate among different AQCRs, it is obvious that the air quality standard to be implemented in the 305(a) Report will have considerably different economic

### TABLE 6.2
### CHANGE OF UNEMPLOYMENT RATE FROM SIMULATION OF THREE APC STRATEGIES

| AQCR Code | AQCR | Change of Unemployment Rate (%) Strategy 1 | Strategy 2 | Strategy 3 |
|---|---|---|---|---|
| 1 | New York, N. Y. | 0.17 | 0.13 | 0.07 |
| 2 | Chicago, Ill. | 1.38 | 1.15 | 0.69 |
| 3 | Los Angeles, Calif. | -0.003 | 0.02 | 0.03 |
| 4 | Philadelphia, Pa. | 0.58 | 0.46 | 0.29 |
| 5 | Detroit, Mich. | 1.21 | 1.07 | 0.62 |
| 6 | San Francisco, Calif. | -0.03 | 0.07 | 0.13 |
| 7 | Boston, Mass. | 0.28 | 0.24 | 0.26 |
| 8 | Pittsburgh, Pa. | 2.06 | 1.57 | 1.03 |
| 9 | St. Louis, Mo. | 1.74 | 1.53 | 0.91 |
| 10 | Washington, D. C. | 0.22 | 0.13 | 0.06 |
| 11 | Cleveland, Ohio | 0.98 | 0.60 | 0.40 |
| 12 | Baltimore, Md. | 1.00 | 0.81 | 0.47 |
| 14 | Minneapolis-St. Paul, Minn. | 0.53 | 0.47 | 0.15 |
| 15 | Houston, Texas | 0.49 | 0.58 | 0.39 |
| 16 | Buffalo, N. Y. | 1.40 | 1.08 | 0.69 |
| 17 | Milwaukee, Wis. | 1.39 | 1.20 | 0.86 |
| 18 | Cincinnati, Ohio | 1.54 | 1.14 | 0.58 |
| 19 | Louisville, Ky. | 1.58 | 1.39 | 0.96 |
| 20 | Dallas, Texas | 0.13 | 0.08 | 0.02 |
| 21 | Seattle-Everett, Wash. | 0.09 | 0.03 | 0.06 |
| 22 | Kansas City, Mo. | 0.25 | 0.22 | 0.16 |
| 23 | San Diego, Calif. | -0.03 | -0.02 | -0.01 |
| 24 | Atlanta, Ga. | 0.08 | 0.04 | 0.06 |
| 25 | Indianapolis, Ind. | 0.78 | 0.67 | 0.31 |
| 26 | Miami, Fla. | 0.03 | -0.01 | 0.0 |
| 27 | Denver, Colo. | 0.51 | 0.38 | 0.20 |
| 28 | New Orleans, La. | 0.52 | 0.12 | 0.08 |
| 29 | Portland, Ore. | 0.40 | 0.15 | 0.08 |
| 30 | Providence-Pawtucket, R.I. | 0.23 | 0.18 | 0.14 |
| 31 | Phoenix, Ariz. | 0.29 | 0.17 | 0.09 |
| 32 | Tampa, Fla. | 0.47 | 0.29 | 0.15 |
| 33 | Columbus, Ohio | 0.07 | 0.04 | 0.02 |
| 34 | San Antonio, Texas | 0.12 | 0.04 | 0.02 |
| 35 | Dayton, Ohio | 0.78 | 0.63 | 0.45 |
| 36 | Birmingham, Ala. | 1.95 | 1.51 | 1.10 |
| 37 | Toledo, Ohio | 0.91 | 0.78 | 0.44 |
| 38 | Steubenville-Weirton, Ohio/W. Va. | 8.89 | 7.37 | 3.92 |
| 39 | Chattanooga, Tenn. | 0.43 | 0.45 | 0.13 |

TABLE 6. 2 (continued)

| | | Change of Unemployment Rate (%) | | |
|---|---|---|---|---|
| AQCR Code | AQCR | Strategy 1 | Strategy 2 | Strategy 3 |
| 40 | Memphis, Tenn. | -0. 03 | -0. 04 | -0. 02 |
| 41 | Salt Lake City, Utah | 0. 72 | 0. 38 | 0. 19 |
| 42 | Oklahoma City, Okla. | 0. 31 | 0. 18 | 0. 12 |
| 43 | Omaha, Neb. | 0. 69 | 0. 51 | 0. 22 |
| 44 | Honolulu, Hawaii | 0. 18 | 0. 12 | -0. 05 |
| 45 | Beaumont-Port Arthur-Orange, Texas | 0. 77 | 0. 18 | 0. 09 |
| 46 | Charlotte, N. C. | 0. 50 | 0. 35 | 0. 16 |
| 47 | Portland, Maine | 0. 07 | -0. 74 | 0. 20 |
| 48 | Albuquerque, N. M. | 0. 02 | 0. 08 | -0. 02 |
| 49 | Lawrence-Haverhill/Lowell, Mass. | 0. 87 | 0. 79 | 0. 39 |
| 50 | El Paso, Texas | 0. 35 | 0. 11 | 0. 09 |
| 51 | Las Vegas, Nev. | 0. 16 | 0. 13 | 0. 07 |
| 52 | Fargo-Moorhead, N. D., Minn. | 0. 57 | 0. 25 | 0. 12 |
| 53 | Boise, Idaho | 0. 29 | 0. 11 | 0. 07 |
| 54 | Billings, Montana | 0. 30 | 0. 05 | 0. 03 |
| 55 | Sioux City, Iowa | 0. 02 | -0. 01 | -0. 06 |
| 61 | Allentown-Bethelehem-Easton, Pa., N. J. | 2. 03 | 1. 56 | 1. 24 |
| 63 | Bakersfield, Calif. | 0. 22 | 0. 05 | 0. 02 |
| 64 | Davenport-Rock Island-Moline, Iowa, Ill. | 1. 22 | 0. 95 | 0. 61 |
| 66 | Grand Rapids/Muskegon-Muskegon Hts., Mich. | 1. 61 | 1. 45 | 0. 69 |
| 67 | Greensboro, N. C. | 0. 08 | 0. 05 | 0. 02 |
| 68 | Harrisburg, Pa. | 1. 14 | 0. 69 | 0. 31 |
| 69 | Jacksonville, Fla. | 0. 25 | 0. 10 | 0. 02 |
| 70 | Knoxville, Tenn. | 1. 04 | 0. 50 | 0. 20 |
| 71 | Nashville, Tenn. | 0. 08 | 0. 09 | 0. 05 |
| 72 | Peoria, Ill. | 1. 80 | 1. 54 | 0. 81 |
| 73 | Richmond, Va. | 0. 45 | 0. 35 | 0. 20 |
| 74 | Rochester, N. Y. | -0. 53 | 0. 22 | -0. 17 |
| 75 | Saginaw/Bay City, Mich. | 5. 23 | 4. 67 | 2. 35 |
| 76 | Scranton-Wilkes Barre-Hazelton, Pa. | 5. 27 | 4. 49 | 2. 25 |
| 77 | Syracuse, N. Y. | 0. 33 | 0. 30 | 0. 23 |
| 78 | Tulsa, Okla. | 0. 61 | 0. 33 | 0. 17 |

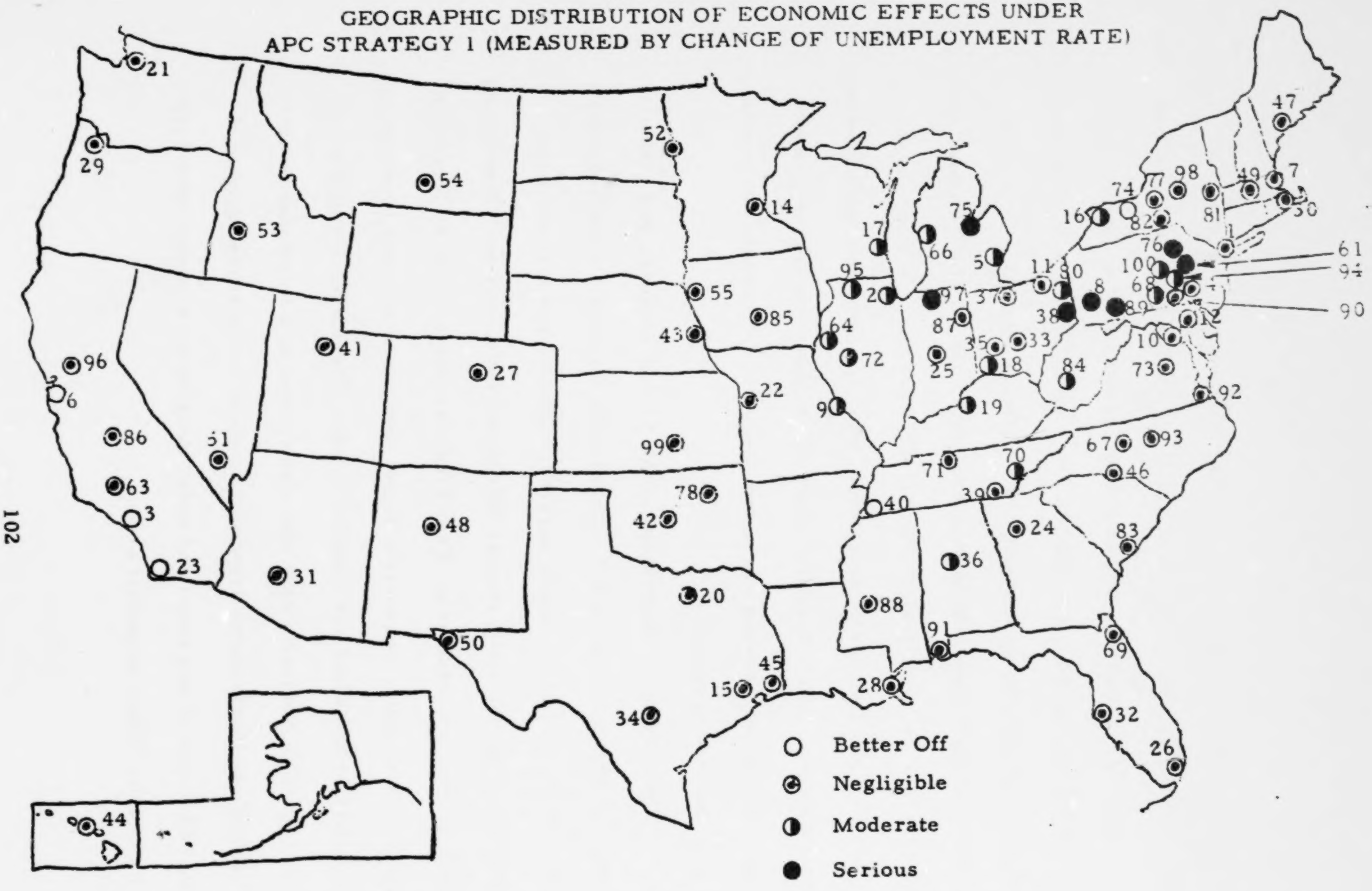
TABLE 6.2 (continued)

| AQCR Code | AQCR | Change of Unemployment Rate (%) | | |
|---|---|---|---|---|
| | | Strategy 1 | Strategy 2 | Strategy 3 |
| 80 | Youngstown-Warren, O. | 1.69 | 1.13 | 0.61 |
| 81 | Albany-Schenectady-Troy, N. Y. | 0.28 | 0.22 | 0.15 |
| 82 | Binghamton, N. Y. | 0.84 | 0.65 | 0.32 |
| 83 | Charleston, S. C. | 0.51 | 0.24 | 0.12 |
| 84 | Charleston, W. Va. | 1.73 | 1.48 | 0.74 |
| 85 | Des Moines, Iowa | 0.79 | 0.59 | 0.30 |
| 86 | Fresno, Calif. | 0.07 | 0.01 | 0.01 |
| 87 | Fort Wayne, Ind. | 0.91 | 0.73 | 0.36 |
| 88 | Jackson, Miss. | 0.01 | -0.28 | 0.05 |
| 89 | Johnstown, Pa. | 2.07 | 1.25 | 0.62 |
| 90 | Lancaster, Pa. | 0.77 | 0.62 | 0.34 |
| 91 | Mobile, Ala. | 0.64 | 0.43 | 0.20 |
| 92 | Norfolk-Portsmouth/Newport News-Hampton, Va. | 0.42 | 0.21 | 0.11 |
| 93 | Raleigh/Durham, N. C. | 0.77 | 0.61 | 0.30 |
| 94 | Reading, Pa. | 1.52 | 1.23 | 0.75 |
| 95 | Rockford, Ill. | 1.47 | 1.34 | 0.70 |
| 96 | Sacramento, Calif. | 0.02 | 0.01 | 0.0 |
| 97 | South Bend, Ind. | 2.05 | 1.66 | 0.86 |
| 98 | Utica-Rome, N. Y. | 0.42 | 0.35 | 0.25 |
| 99 | Wichita, Kan. | 0.01 | -0.07 | -0.03 |
| 100 | York, Pa. | 1.08 | 0.92 | 0.48 |

effects on each AQCR. Some AQCRs, for example, Steubenville-Weirton, Pittsburgh, etc., will possibly expect a 2 percent or more increase in the regional unemployment. However, for others, the impacts are negligible; some AQCRs are even better off with a decrease in employment rate as a result of air pollution control. This could mean that higher air quality standards for those AQCRs with negligible effects may be "practical." The 91 AQCRs under this study can be classified into four major categories, namely, better off (decrease in unemployment rate), negligible (increases under one percent), moderate (increases between one to two percent), and serious (increases more than two percent).

The geographic distribution of all 91 AQCRs under this classification is shown in Figure 6.2. Under APC Strategy 1 (Industry Pays), most of the AQCRs seriously adversely affected are located in the heavily industrial north-central (Michigan, Ohio, Indiana, Illinois) and central-east (Pennsylvania, West Virginia) states. AQCRs located in the west and south, in general, do not seem to be affected by air pollution control and some are even better off. Therefore, air pollution control under Strategy 1 may conceivably lead to a locational redistribution of the economic activity of the nation, by increased growth in the new metropolitan areas and under the greater economic pressure on the older heavy industrial areas.

FIGURE 6.2
GEOGRAPHIC DISTRIBUTION OF ECONOMIC EFFECTS UNDER
APC STRATEGY 1 (MEASURED BY CHANGE OF UNEMPLOYMENT RATE)


21
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55
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43
41
27
96
6
86
51
63
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99
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50
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45
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97
37
64
72
87
25
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33
18
9
19
11
30
8
38
89
84
16
74
77
98
81
49
7
47
30
82
76
100
68
61
94
90
1
12
10
73
92
67
93
46
71
70
39
40
24
83
36
88
91
28
69
32
26
44
○ Better Off
◉ Negligible
◑ Moderate
● Serious

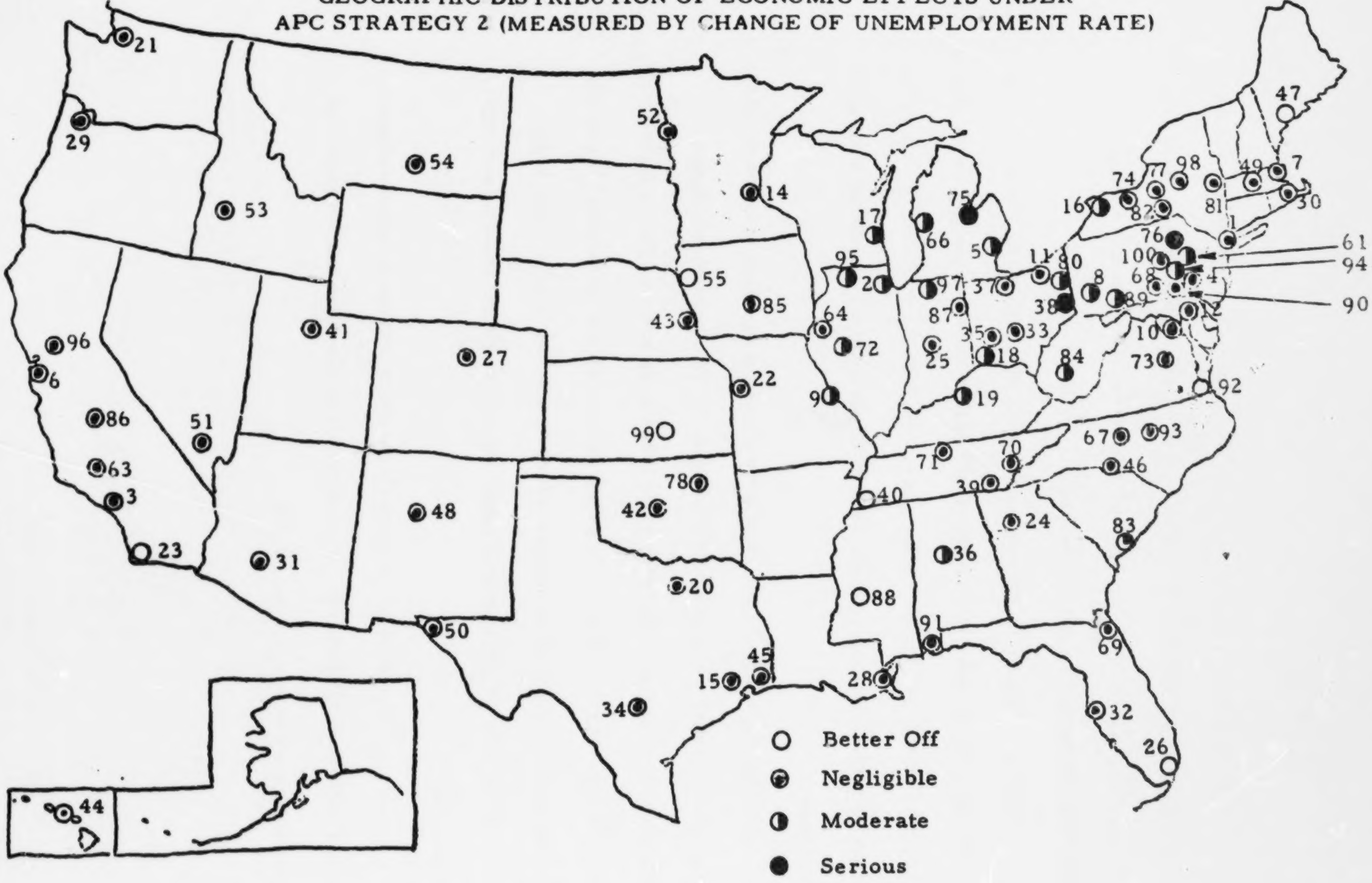
The geographic distribution of the outputs from Strategy 2 and Strategy 3 is provided in Figures 6.3 and 6.4, respectively. By comparing the outputs for alternative strategies, the economic effects of different strategies seem to be clear.

Under Strategy 2, the high emission industries, to some degree, would be able to pass on a portion of control costs to the public as price increase in the products. Therefore, the AQCRs with heavy concentrations of high emission industries will be in a better condition than under Strategy 1.

Under Strategy 3, the cost pressures on the high emission industries are further released by 50 percent of government subsidies. Therefore, those AQCRs with such industries are improved further than in Strategy 2. However, price increases and additional taxes (for pollution subsidies) will have an adverse economic effect on those AQCRs with large populations (and, hence, regional income and consumption).

The number of AQCRs in each category changes considerably under different strategies. The percentage distribution between the four categories is provided below:

FIGURE 6. 3
GEOGRAPHIC DISTRIBUTION OF ECONOMIC EFFECTS UNDER APC STRATEGY 2 (MEASURED BY CHANGE OF UNEMPLOYMENT RATE)


21
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86
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50
99
22
78
42
20
34
15
45
17
95
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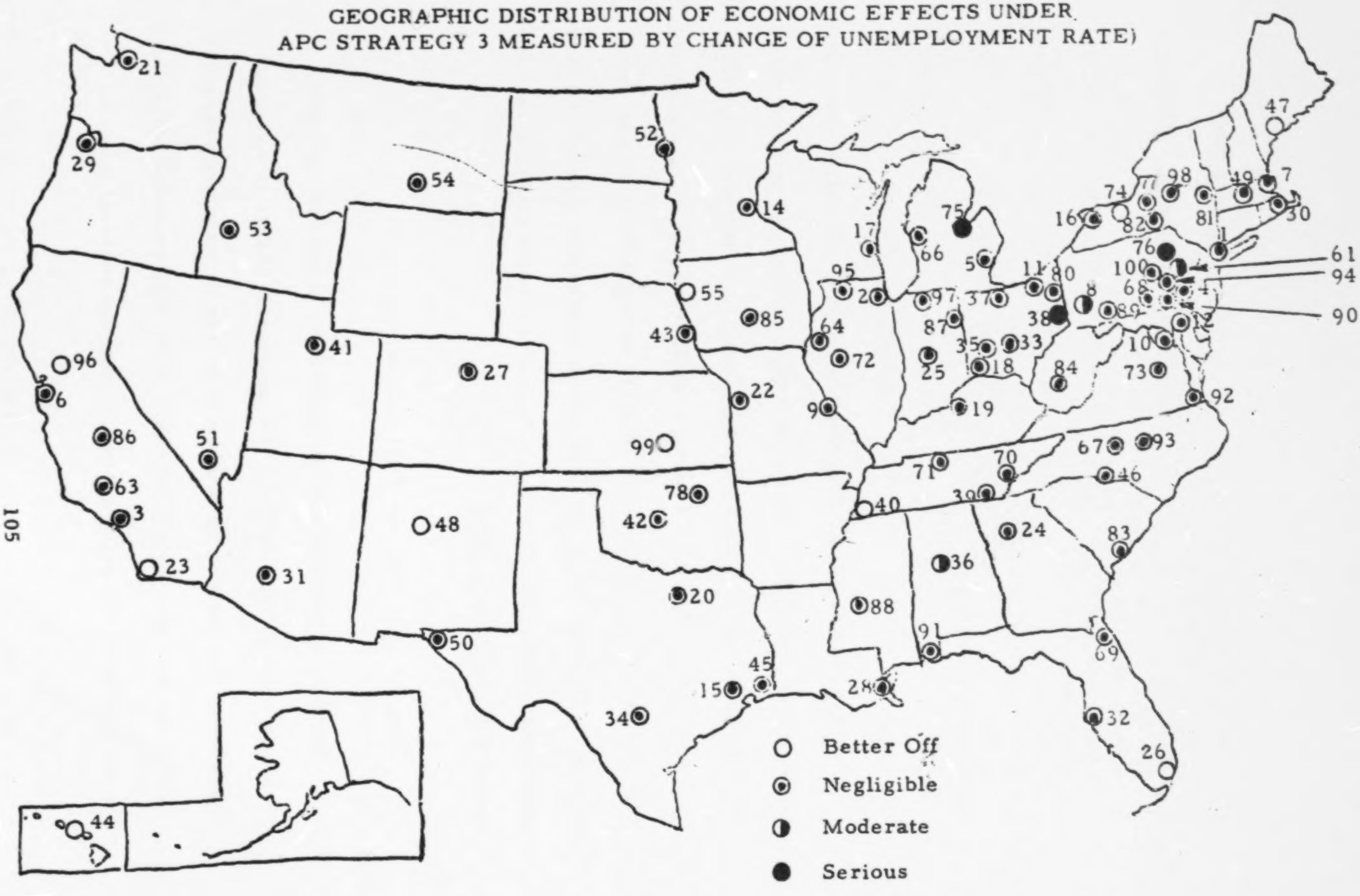
64
72
9
66
75
5
97
37
87
35
33
25
18
19
11
80
38
84
16
74
77
98
82
81
49
7
47
30
1
76
100
61
94
90
68
4
8
89
12
10
73
92
67
93
46
71
70
39
40
24
83
36
88
91
28
69
32
26
44
○ Better Off
◉ Negligible
◑ Moderate
● Serious

FIGURE 6.4
GEOGRAPHIC DISTRIBUTION OF ECONOMIC EFFECTS UNDER
APC STRATEGY 3 MEASURED BY CHANGE OF UNEMPLOYMENT RATE)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52
14
53
17
95
66
75
47
98
49
7
74
16
82
81
30
1
76
61
94
90
100
68
4
8
89
11
80
5
20
97
37
38
55
85
43
64
72
87
35
33
12
10
41
27
96
6
25
18
84
73
22
9
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92
86
51
99
67
93
71
70
46
63
78
39
3
42
40
24
48
83
23
31
36
20
88
50
91
69
45
15
28
32
34
26
44
○ Better Off
◉ Negligible
◐ Moderate
● Serious

| Categories of Change of Unemployment Rate (%) in AQCRs | AQCRs Included (%) Strategy 1 | Strategy 2 | Strategy 3 |
|---|---|---|---|
| 1. Better off (increase in employment) | 5.5% | 7.7% | 9.9% |
| 2. Negligible (0.01% to 1.00%) | 67.0% | 69.2% | 83.5% |
| 3. Moderate (1.01% to 2.0%) | 19.8% | 19.8% | 3.3% |
| 4. Serious (2.01% and over) | 7.7% | 3.3% | 3.3% |
| Total | 100.0% | 100.0% | 100.0% |

Under Strategy 1, 27.5 percent of AQCRs will have a moderate or serious economic effect with an increase of more than one percent of unemployment rate. This figure is reduced to 23 percent under Strategy 2 and further down to 6.6 percent under Strategy 3. In other words, regional difference of economic impacts among AQCRs will be much greater in Strategy 1 and Strategy 2 than Strategy 3, although all three alternative strategies were under "same" emission standard specified in the 305(a) Report of 1970.

### 6.4 Changes in Profits and Personal Income

Unemployment rate, though important, is but one indicator. Consequently, this section explores the patterns of change in two other key indicators. The first is the decline in profits of manufacturing industries in the AQCRs -- a key indicator of the high emission industries. The second indicator is the decline in regional personal income.

The changes by region, in the unemployment rate, and percentage changes in personal income and profits under each policy, are presented in Tables 6.3 through 6.5. For each column, the median and quartiles have been identified. The figure beside each number indicates the quartile in which the region falls where (1) indicates least negatively affected quartile, and (4) indicates most negatively affected quartile. In addition, a rank column has been placed by each result column ranking the AQCRs from least negatively affected to most negatively affected.

These tables, singularly and severally, tell an interesting story. First, for any given strategy, there appears to be rough consistency as between the quartile rankings of any given AQCR for each of the three indicators of economic activity selected for analysis. That is, if unemployment increases a relatively great amount in some region, personal income and profits decrease by a relatively great amount. There also appears to be a rough consistency between the ranking of an AQCR for the changes arrayed for any given policy. It would, indeed, be interesting and perhaps informative exercise to look at the rank correlation coefficients between these various measures.

For all indicators studied here, in fact, median values tend to decrease as incidence becomes less geographically localized. The

## TABLE 6.3

## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 1

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.1741 | 22 | 1 | -0.5759 | 43 | 2 | -0.0772 | 17 | 1 |
| 2 | 1.3850 | 72 | 4 | -1.8681 | 80 | 4 | -0.8325 | 67 | 3 |
| 3 | -0.0034 | 7 | 1 | -0.0177 | 10 | 1 | 0.0303 | 5 | 1 |
| 4 | 0.5851 | 50 | 3 | -0.7452 | 50 | 3 | -0.3880 | 47 | 3 |
| 5 | 1.2074 | 70 | 4 | -1.5538 | 77 | 4 | -0.6638 | 61 | 3 |
| 6 | -0.0380 | 2 | 1 | -0.0297 | 11 | 1 | 0.0847 | 2 | 1 |
| 7 | 0.2775 | 29 | 2 | -0.3103 | 28 | 2 | -0.1329 | 22 | 1 |
| 8 | 2.0567 | 86 | 4 | -4.3805 | 89 | 4 | -1.8569 | 85 | 4 |
| 9 | 1.7359 | 82 | 4 | -2.1337 | 83 | 4 | -1.0087 | 74 | 4 |
| 10 | 0.2174 | 24 | 2 | -2.9775 | 86 | 4 | -0.1485 | 23 | 1 |
| 11 | 0.9812 | 65 | 3 | -1.8266 | 79 | 4 | -0.8609 | 69 | 3 |
| 12 | 1.0027 | 66 | 3 | -1.2875 | 70 | 4 | -0.7273 | 65 | 3 |
| 14 | 0.5293 | 48 | 3 | -0.6567 | 48 | 3 | -0.2745 | 32 | 2 |
| 15 | 0.4904 | 43 | 2 | -0.2687 | 25 | 2 | -0.3593 | 41 | 2 |
| 16 | 1.4004 | 74 | 4 | -2.1073 | 82 | 4 | -1.3009 | 82 | 4 |
| 17 | 1.3947 | 73 | 4 | -1.1307 | 68 | 3 | -0.8505 | 68 | 3 |
| 18 | 1.5448 | 77 | 4 | -1.4598 | 75 | 4 | -0.8754 | 70 | 4 |
| 19 | 1.5802 | 78 | 4 | -1.0973 | 67 | 3 | -0.9246 | 71 | 4 |
| 20 | 0.1312 | 20 | 1 | -0.1315 | 16 | 1 | -0.1060 | 20 | 1 |
| 21 | 0.0946 | 18 | 1 | -0.2603 | 24 | 2 | -0.0631 | 16 | 1 |
| 22 | 0.2510 | 28 | 2 | -0.3093 | 27 | 2 | -0.1560 | 24 | 2 |
| 23 | -0.0303 | 3 | 1 | 0.0887 | 6 | 1 | 0.0301 | 6 | 1 |
| 24 | 0.0763 | 15 | 1 | -0.4437 | 33 | 2 | 0.0080 | 7 | 1 |
| 25 | 0.7753 | 58 | 3 | -0.7649 | 53 | 3 | -0.4213 | 49 | 3 |
| 26 | 0.0291 | 11 | 1 | -0.2047 | 20 | 1 | -0.0478 | 15 | 1 |
| 27 | 0.5057 | 45 | 2 | -1.4104 | 73 | 4 | -0.3106 | 35 | 2 |
| 28 | 0.5179 | 47 | 3 | -0.8355 | 55 | 3 | -0.6643 | 62 | 3 |
| 29 | 0.3992 | 37 | 2 | -0.7502 | 51 | 3 | -0.4447 | 50 | 3 |
| 30 | 0.2309 | 26 | 2 | -0.3380 | 29 | 2 | -0.1783 | 25 | 2 |
| 31 | 0.2901 | 31 | 2 | -0.2044 | 19 | 1 | -0.2474 | 30 | 2 |

## TABLE 6.3 (continued)
## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 1

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 0.4742 | 42 | 2 | -1.4185 | 74 | 4 | -0.3768 | 44 | 2 |
| 33 | 0.0681 | 12 | 1 | -0.0554 | 14 | 1 | -0.0438 | 14 | 1 |
| 34 | 0.1195 | 19 | 1 | -0.5954 | 44 | 2 | -0.1233 | 21 | 1 |
| 35 | 0.7827 | 59 | 3 | -0.7164 | 49 | 3 | -0.5055 | 52 | 3 |
| 36 | 1.9490 | 84 | 4 | -3.9978 | 88 | 4 | -2.1093 | 88 | 4 |
| 37 | 0.9080 | 64 | 3 | -1.0426 | 63 | 3 | -0.5222 | 53 | 3 |
| 38 | 8.8929 | 91 | 4 | -6.7709 | 91 | 4 | -12.0438 | 91 | 4 |
| 39 | 0.4265 | 40 | 2 | -0.2110 | 21 | 1 | -0.3667 | 43 | 2 |
| 40 | -0.0284 | 4 | 1 | 0.0983 | 4 | 1 | 0.0673 | 4 | 1 |
| 41 | 0.7163 | 54 | 3 | -0.8865 | 57 | 3 | -0.6629 | 60 | 3 |
| 42 | 0.3130 | 34 | 2 | -1.0664 | 65 | 3 | -0.3216 | 36 | 2 |
| 43 | 0.6940 | 53 | 3 | -0.4881 | 35 | 2 | -0.3869 | 46 | 2 |
| 44 | 0.1757 | 23 | 1 | -0.5232 | 39 | 2 | -0.1013 | 19 | 1 |
| 45 | 0.7718 | 57 | 3 | -0.0497 | 13 | 1 | -0.9856 | 73 | 4 |
| 46 | 0.4986 | 44 | 2 | -0.5148 | 37 | 2 | -0.3625 | 42 | 2 |
| 47 | 0.0726 | 14 | 1 | -0.4591 | 34 | 2 | -0.3381 | 37 | 2 |
| 48 | 0.0199 | 10 | 1 | -0.3007 | 26 | 2 | -0.0248 | 10 | 1 |
| 49 | 0.8728 | 62 | 3 | -1.0052 | 61 | 3 | -1.1710 | 79 | 4 |
| 50 | 0.3488 | 36 | 2 | -0.7613 | 52 | 3 | -0.4044 | 48 | 3 |
| 51 | 0.1643 | 21 | 1 | -0.5383 | 41 | 2 | -0.1807 | 26 | 2 |
| 52 | 0.5717 | 49 | 3 | 0.4038 | 1 | 1 | -0.5441 | 54 | 3 |
| 53 | 0.2932 | 32 | 2 | -0.5470 | 42 | 2 | -0.2882 | 33 | 2 |
| 54 | 0.3017 | 33 | 2 | 0.0691 | 7 | 1 | -0.3472 | 38 | 2 |
| 55 | 0.0194 | 9 | 1 | 0.1336 | 3 | 1 | 0.0679 | 3 | 1 |
| 61 | 2.0333 | 85 | 4 | -2.2695 | 84 | 4 | -1.6683 | 84 | 4 |
| 63 | 0.2176 | 25 | 2 | -0.5119 | 36 | 2 | -0.1870 | 27 | 2 |
| 64 | 1.2150 | 71 | 4 | -0.5209 | 38 | 2 | -1.0585 | 75 | 4 |
| 66 | 1.6144 | 79 | 4 | -1.5296 | 76 | 4 | -0.9517 | 72 | 4 |
| 67 | 0.0766 | 16 | 1 | -0.0064 | 9 | 1 | -0.0281 | 12 | 1 |
| 68 | 1.1409 | 69 | 3 | -1.7794 | 78 | 4 | -1.0803 | 77 | 4 |

## TABLE 6.3 (continued)
## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 1

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 69 | 0.2502 | 27 | 2 | -0.6084 | 45 | 2 | -0.2712 | 31 | 2 |
| 70 | 1.0365 | 67 | 3 | -0.9269 | 59 | 3 | -1.1647 | 78 | 4 |
| 71 | 0.0766 | 17 | 1 | 0.0971 | 5 | 1 | -0.0430 | 13 | 1 |
| 72 | 1.8022 | 83 | 4 | -0.9415 | 60 | 3 | -1.0764 | 76 | 4 |
| 73 | 0.4490 | 41 | 2 | -0.2514 | 23 | 1 | -0.3089 | 34 | 2 |
| 74 | -0.5312 | 1 | 1 | 0.0042 | 8 | 1 | 0.3802 | 1 | 1 |
| 75 | 5.2258 | 89 | 4 | -3.3248 | 87 | 4 | -2.6546 | 89 | 4 |
| 76 | 5.2672 | 90 | 4 | -4.6192 | 90 | 4 | -3.6113 | 90 | 4 |
| 77 | 0.3257 | 35 | 2 | -0.1973 | 18 | 1 | -0.2157 | 29 | 2 |
| 78 | 0.6129 | 51 | 3 | -1.0661 | 64 | 3 | -0.5510 | 56 | 3 |
| 80 | 1.6879 | 80 | 4 | -2.0096 | 81 | 4 | -1.9618 | 86 | 4 |
| 81 | 0.2815 | 30 | 2 | -0.3918 | 31 | 2 | -0.2080 | 28 | 2 |
| 82 | 0.8404 | 61 | 3 | -0.5369 | 40 | 2 | -0.5480 | 55 | 3 |
| 83 | 0.5143 | 46 | 2 | -0.9075 | 58 | 3 | -0.5832 | 57 | 3 |
| 84 | 1.7346 | 81 | 4 | -1.3058 | 71 | 4 | -1.2865 | 81 | 4 |
| 85 | 0.7975 | 60 | 3 | -1.0796 | 66 | 3 | -0.6645 | 63 | 3 |
| 86 | 0.0681 | 13 | 1 | -0.1798 | 17 | 1 | -0.0894 | 18 | 1 |
| 87 | 0.9059 | 63 | 3 | -0.8417 | 56 | 3 | -0.6359 | 59 | 3 |
| 88 | -0.0058 | 6 | 1 | -0.1189 | 15 | 1 | -0.0016 | 8 | 1 |
| 89 | 2.0708 | 88 | 4 | -2.9529 | 85 | 4 | -2.0432 | 87 | 4 |
| 90 | 0.7706 | 56 | 3 | -0.6337 | 46 | 2 | -0.6940 | 64 | 3 |
| 91 | 0.6360 | 52 | 3 | -0.8280 | 54 | 3 | -0.4740 | 51 | 3 |
| 92 | 0.4220 | 39 | 2 | -1.1985 | 69 | 3 | -0.3776 | 45 | 2 |
| 93 | 0.7677 | 55 | 3 | -0.4098 | 32 | 2 | -0.3589 | 40 | 2 |
| 94 | 1.5157 | 76 | 4 | -1.0319 | 62 | 3 | -1.1798 | 80 | 4 |
| 95 | 1.4734 | 75 | 4 | -0.3757 | 30 | 2 | -0.7762 | 66 | 3 |
| 96 | 0.0178 | 8 | 1 | -0.0404 | 12 | 1 | -0.0227 | 9 | 1 |
| 97 | 2.0593 | 87 | 4 | -1.3659 | 72 | 4 | -1.3341 | 83 | 4 |
| 98 | 0.4194 | 38 | 2 | -0.2200 | 22 | 1 | -0.3563 | 39 | 2 |
| 99 | -0.0138 | 5 | 1 | 0.1466 | 2 | 1 | -0.0251 | 11 | 1 |
| 100 | 1.0832 | 68 | 3 | -0.6439 | 47 | 3 | -0.6172 | 58 | 3 |

## TABLE 6.4

## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 2

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.1290 | 28 | 2 | -0.2086 | 38 | 2 | -0.0298 | 17 | 1 |
| 2 | 1.1541 | 75 | 4 | -0.9241 | 77 | 4 | -0.5672 | 71 | 4 |
| 3 | 0.0233 | 10 | 1 | 0.0055 | 8 | 1 | -0.0014 | 11 | 1 |
| 4 | 0.4594 | 51 | 3 | -0.3901 | 53 | 3 | -0.2394 | 53 | 3 |
| 5 | 1.0678 | 71 | 4 | -0.9805 | 79 | 4 | -0.5200 | 70 | 4 |
| 6 | 0.0749 | 18 | 1 | -0.0153 | 12 | 1 | -0.0245 | 16 | 1 |
| 7 | 0.2380 | 39 | 2 | -0.1558 | 30 | 2 | -0.0910 | 28 | 2 |
| 8 | 1.5702 | 87 | 4 | -2.2961 | 88 | 4 | -1.2675 | 87 | 4 |
| 9 | 1.5329 | 84 | 4 | -1.2837 | 84 | 4 | -0.7640 | 78 | 4 |
| 10 | 0.1257 | 27 | 2 | -0.9358 | 78 | 4 | -0.0559 | 23 | 1 |
| 11 | 0.5983 | 57 | 3 | -0.8366 | 74 | 4 | -0.4117 | 65 | 3 |
| 12 | 0.8060 | 68 | 3 | -0.7327 | 70 | 4 | -0.4924 | 69 | 3 |
| 14 | 0.4729 | 52 | 3 | -0.3125 | 49 | 3 | -0.2003 | 48 | 3 |
| 15 | 0.5811 | 55 | 3 | -0.1317 | 25 | 2 | -0.4418 | 67 | 3 |
| 16 | 1.0833 | 72 | 4 | -1.2047 | 83 | 4 | -0.8931 | 82 | 4 |
| 17 | 1.1975 | 76 | 4 | -0.7096 | 69 | 3 | -0.6022 | 72 | 4 |
| 18 | 1.1433 | 74 | 4 | -0.6951 | 68 | 3 | -0.4295 | 66 | 3 |
| 19 | 1.3923 | 80 | 4 | -0.5938 | 62 | 3 | -0.6888 | 74 | 4 |
| 20 | 0.0804 | 20 | 1 | -0.0512 | 19 | 1 | -0.0455 | 22 | 1 |
| 21 | 0.0279 | 11 | 1 | -0.0218 | 16 | 1 | 0.0003 | 10 | 1 |
| 22 | 0.2169 | 36 | 2 | -0.1541 | 29 | 2 | -0.1130 | 30 | 2 |
| 23 | -0.0219 | 5 | 1 | 0.0669 | 5 | 1 | 0.0217 | 8 | 1 |
| 24 | 0.0360 | 13 | 1 | -0.1453 | 28 | 2 | 0.0611 | 7 | 1 |
| 25 | 0.6666 | 62 | 3 | -0.4332 | 57 | 3 | -0.2929 | 55 | 3 |
| 26 | -0.0148 | 6 | 1 | -0.0160 | 13 | 1 | -0.0019 | 12 | 1 |
| 27 | 0.3834 | 48 | 3 | -0.5753 | 61 | 3 | -0.1643 | 41 | 2 |
| 28 | 0.1200 | 26 | 2 | -0.1794 | 34 | 2 | -0.1502 | 38 | 2 |
| 29 | 0.1466 | 30 | 2 | -0.1833 | 35 | 2 | -0.1404 | 37 | 2 |
| 30 | 0.1848 | 33 | 2 | -0.1732 | 32 | 2 | -0.1192 | 31 | 2 |
| 31 | 0.1698 | 31 | 2 | -0.1138 | 22 | 1 | -0.1029 | 29 | 2 |

## TABLE 6.4 (continued)
## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 2

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 0.2898 | 41 | 2 | -0.6123 | 63 | 3 | -0.1557 | 39 | 2 |
| 33 | 0.0360 | 12 | 1 | -0.0198 | 14 | 1 | -0.0020 | 13 | 1 |
| 34 | 0.0446 | 14 | 1 | -0.2052 | 37 | 2 | -0.0346 | 18 | 1 |
| 35 | 0.6327 | 60 | 3 | -0.4063 | 56 | 3 | -0.3308 | 57 | 3 |
| 36 | 1.5072 | 83 | 4 | -2.1350 | 87 | 4 | -1.4813 | 88 | 4 |
| 37 | 0.7756 | 65 | 3 | -0.5692 | 60 | 3 | -0.3728 | 58 | 3 |
| 38 | 7.3687 | 91 | 4 | -3.0258 | 90 | 4 | -8.0880 | 91 | 4 |
| 39 | 0.4463 | 50 | 3 | -0.0829 | 20 | 1 | -0.3922 | 62 | 3 |
| 40 | -0.0363 | 4 | 1 | 0.0735 | 4 | 1 | 0.0720 | 6 | 1 |
| 41 | 0.3819 | 47 | 3 | -0.2759 | 44 | 2 | -0.2312 | 52 | 3 |
| 42 | 0.1753 | 32 | 2 | -0.6231 | 64 | 3 | -0.1271 | 34 | 2 |
| 43 | 0.5088 | 54 | 3 | -0.2200 | 41 | 2 | -0.1661 | 42 | 2 |
| 44 | 0.1153 | 25 | 2 | -0.1168 | 23 | 1 | -0.0407 | 19 | 1 |
| 45 | 0.7802 | 66 | 3 | -0.0113 | 11 | 1 | -0.2292 | 51 | 3 |
| 46 | 0.3502 | 45 | 2 | -0.2317 | 43 | 2 | -0.1631 | 40 | 2 |
| 47 | -0.7406 | 1 | 1 | -0.2198 | 40 | 2 | 0.5802 | 1 | 1 |
| 48 | 0.0776 | 19 | 1 | -0.0204 | 15 | 1 | -0.0898 | 27 | 2 |
| 49 | 0.7851 | 67 | 3 | -0.8491 | 75 | 4 | -0.9060 | 83 | 4 |
| 50 | 0.1112 | 23 | 1 | -0.1367 | 26 | 2 | -0.1265 | 33 | 2 |
| 51 | 0.1301 | 29 | 2 | -0.1122 | 21 | 1 | -0.1276 | 36 | 2 |
| 52 | 0.2502 | 40 | 2 | -0.3681 | 50 | 3 | -0.1697 | 43 | 2 |
| 53 | 0.1138 | 24 | 2 | -0.1389 | 27 | 2 | -0.0795 | 26 | 2 |
| 54 | 0.0492 | 15 | 1 | 0.1058 | 3 | 1 | -0.0420 | 20 | 1 |
| 55 | -0.0132 | 7 | 1 | 0.2249 | 1 | 1 | 0.0985 | 4 | 1 |
| 61 | 1.5642 | 86 | 4 | -1.4259 | 85 | 4 | -1.0557 | 85 | 4 |
| 63 | 0.0539 | 17 | 1 | -0.1168 | 24 | 2 | -0.0455 | 21 | 1 |
| 64 | 0.9514 | 70 | 4 | -0.3859 | 52 | 3 | -0.7013 | 75 | 4 |
| 66 | 1.4548 | 81 | 4 | -1.1449 | 82 | 4 | -0.7463 | 76 | 4 |
| 67 | 0.0497 | 16 | 1 | 0.0026 | 9 | 1 | 0.0078 | 9 | 1 |
| 68 | 0.6891 | 63 | 3 | -1.0432 | 80 | 4 | 0.4522 | 2 | 1 |

## TABLE 6.4 (continued)
## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 2

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 69 | 0.0958 | 22 | 1 | -0.2110 | 39 | 2 | -0.0780 | 25 | 2 |
| 70 | 0.5045 | 53 | 3 | -0.3738 | 51 | 3 | -0.3851 | 60 | 3 |
| 71 | 0.0934 | 21 | 1 | 0.0431 | 7 | 1 | -0.0676 | 24 | 2 |
| 72 | 1.5374 | 85 | 4 | -0.5421 | 59 | 3 | -0.7500 | 77 | 4 |
| 73 | 0.3534 | 46 | 2 | -0.1750 | 33 | 2 | -0.1866 | 45 | 2 |
| 74 | 0.2158 | 35 | 2 | 0.0434 | 6 | 1 | -0.3886 | 61 | 3 |
| 75 | 4.6720 | 90 | 4 | -2.6109 | 89 | 4 | -2.0691 | 89 | 4 |
| 76 | 4.4876 | 89 | 4 | -4.0735 | 91 | 4 | -2.4319 | 90 | 4 |
| 77 | 0.3003 | 42 | 2 | -0.1684 | 31 | 2 | -0.1837 | 44 | 2 |
| 78 | 0.3339 | 43 | 2 | -0.6621 | 67 | 3 | -0.2035 | 49 | 3 |
| 80 | 1.1264 | 73 | 4 | -1.0612 | 81 | 4 | -1.2202 | 86 | 4 |
| 81 | 0.2170 | 37 | 2 | -0.2268 | 42 | 2 | -0.1276 | 35 | 2 |
| 82 | 0.6460 | 61 | 3 | -0.3116 | 48 | 3 | -0.2961 | 56 | 3 |
| 83 | 0.2376 | 38 | 2 | -0.3905 | 54 | 3 | -0.1877 | 46 | 2 |
| 84 | 1.4824 | 82 | 4 | -0.8828 | 76 | 4 | -0.9238 | 84 | 4 |
| 85 | 0.5910 | 56 | 3 | -0.8235 | 73 | 4 | -0.3730 | 59 | 3 |
| 86 | 0.0135 | 9 | 1 | -0.0410 | 18 | 1 | -0.0179 | 15 | 1 |
| 87 | 0.7348 | 64 | 3 | -0.6403 | 65 | 3 | -0.4115 | 64 | 3 |
| 88 | -0.2814 | 2 | 1 | -0.0271 | 17 | 1 | 0.4219 | 3 | 1 |
| 89 | 1.2532 | 78 | 4 | -1.7245 | 86 | 4 | -0.8606 | 81 | 4 |
| 90 | 0.6178 | 59 | 3 | -0.5345 | 58 | 3 | -0.4570 | 68 | 3 |
| 91 | 0.4294 | 49 | 3 | -0.2828 | 45 | 2 | -0.1936 | 47 | 3 |
| 92 | 0.2096 | 34 | 2 | -0.6494 | 66 | 3 | -0.1251 | 32 | 2 |
| 93 | 0.6087 | 58 | 3 | -0.3062 | 47 | 3 | -0.2161 | 50 | 3 |
| 94 | 1.2275 | 77 | 4 | -0.8172 | 72 | 4 | -0.7900 | 79 | 4 |
| 95 | 1.3387 | 79 | 4 | -0.2946 | 46 | 2 | -0.6081 | 73 | 4 |
| 96 | 0.0070 | 8 | 1 | -0.0092 | 10 | 1 | -0.0083 | 14 | 1 |
| 97 | 1.6596 | 88 | 4 | -0.7454 | 71 | 4 | -0.8302 | 80 | 4 |
| 98 | 0.3480 | 44 | 2 | -0.1939 | 36 | 2 | -0.2638 | 54 | 3 |
| 99 | -0.0697 | 3 | 1 | 0.1070 | 2 | 1 | 0.0949 | 5 | 1 |
| 100 | 0.9217 | 69 | 3 | -0.4029 | 55 | 3 | -0.4024 | 63 | 3 |

## TABLE 6.5
## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 3

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.0714 | 25 | 2 | -0.1128 | 34 | 2 | -0.0225 | 22 | 1 |
| 2 | 0.6910 | 75 | 4 | -0.5141 | 76 | 4 | -0.3900 | 72 | 4 |
| 3 | 0.0349 | 18 | 1 | -0.0199 | 14 | 1 | -0.0219 | 21 | 1 |
| 4 | 0.2918 | 55 | 3 | -0.2475 | 54 | 3 | -0.1871 | 57 | 3 |
| 5 | 0.6206 | 73 | 4 | -0.5788 | 81 | 4 | -0.3500 | 69 | 3 |
| 6 | 0.1270 | 35 | 2 | -0.0568 | 21 | 1 | -0.0891 | 37 | 2 |
| 7 | 0.2562 | 54 | 3 | -0.0969 | 27 | 2 | -0.1632 | 54 | 3 |
| 8 | 1.0321 | 86 | 4 | -1.4975 | 89 | 4 | -0.9354 | 86 | 4 |
| 9 | 0.9080 | 84 | 4 | -0.7246 | 82 | 4 | -0.4859 | 80 | 4 |
| 10 | 0.0629 | 23 | 1 | -0.4698 | 73 | 4 | -0.0273 | 23 | 1 |
| 11 | 0.3981 | 65 | 3 | -0.5404 | 79 | 4 | -0.2978 | 66 | 3 |
| 12 | 0.4717 | 68 | 3 | -0.4738 | 74 | 4 | -0.3930 | 73 | 4 |
| 14 | 0.1463 | 39 | 2 | -0.1349 | 39 | 2 | -0.0578 | 27 | 2 |
| 15 | 0.3858 | 63 | 3 | -0.1054 | 32 | 2 | -0.3050 | 67 | 3 |
| 16 | 0.6931 | 76 | 4 | -0.7274 | 83 | 4 | -0.6356 | 84 | 4 |
| 17 | 0.8577 | 82 | 4 | -0.4764 | 75 | 4 | -0.4053 | 74 | 4 |
| 18 | 0.5819 | 70 | 4 | -0.3673 | 67 | 3 | -0.2069 | 61 | 3 |
| 19 | 0.9592 | 85 | 4 | -0.3142 | 60 | 3 | -0.5045 | 81 | 4 |
| 20 | 0.0176 | 12 | 1 | -0.0409 | 19 | 1 | 0.0022 | 12 | 1 |
| 21 | 0.0557 | 21 | 1 | -0.0295 | 18 | 1 | -0.0216 | 19 | 1 |
| 22 | 0.1579 | 42 | 2 | -0.1054 | 33 | 2 | -0.1144 | 45 | 2 |
| 23 | -0.0069 | 7 | 1 | 0.0350 | 4 | 1 | 0.0075 | 10 | 1 |
| 24 | 0.0623 | 22 | 1 | -0.1046 | 30 | 2 | 0.0188 | 8 | 1 |
| 25 | 0.3100 | 59 | 3 | -0.2271 | 53 | 3 | -0.1429 | 51 | 3 |
| 26 | 0.0022 | 9 | 1 | -0.0245 | 16 | 1 | -0.0063 | 13 | 1 |
| 27 | 0.2009 | 47 | 3 | -0.2936 | 57 | 3 | -0.0911 | 38 | 2 |
| 28 | 0.0796 | 27 | 2 | -0.1221 | 35 | 2 | -0.1010 | 43 | 2 |
| 29 | 0.1430 | 38 | 2 | -0.1386 | 41 | 2 | -0.1374 | 50 | 3 |
| 30 | 0.1381 | 37 | 2 | -0.1347 | 38 | 2 | -0.1201 | 48 | 3 |
| 31 | 0.0889 | 29 | 2 | -0.0850 | 25 | 2 | -0.0714 | 30 | 2 |

## TABLE 6.5 (continued)
## CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 3

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 32 | 0.1466 | 40 | 2 | -0.3040 | 58 | 3 | -0.0799 | 32 | 2 |
| 33 | 0.0234 | 15 | 1 | -0.0272 | 17 | 1 | -0.0137 | 16 | 1 |
| 34 | 0.0176 | 11 | 1 | -0.1048 | 31 | 2 | -0.0093 | 15 | 1 |
| 35 | 0.4475 | 67 | 3 | -0.2188 | 52 | 3 | -0.2365 | 64 | 3 |
| 36 | 1.1020 | 87 | 4 | -1.4771 | 88 | 4 | -1.2348 | 90 | 4 |
| 37 | 0.4393 | 66 | 3 | -0.3317 | 64 | 3 | -0.2453 | 65 | 3 |
| 38 | 3.9276 | 91 | 4 | -1.6558 | 90 | 4 | -4.5999 | 91 | 4 |
| 39 | 0.1342 | 36 | 2 | -0.0411 | 20 | 1 | -0.1512 | 52 | 3 |
| 40 | -0.0157 | 6 | 1 | 0.0339 | 5 | 1 | 0.0281 | 5 | 1 |
| 41 | 0.1946 | 46 | 2 | -0.1391 | 42 | 2 | -0.1182 | 47 | 3 |
| 42 | 0.1174 | 34 | 2 | -0.3409 | 66 | 3 | -0.0803 | 34 | 2 |
| 43 | 0.2215 | 51 | 3 | -0.0991 | 28 | 2 | -0.0592 | 28 | 2 |
| 44 | -0.0503 | 3 | 1 | 0.0312 | 6 | 1 | 0.0194 | 7 | 1 |
| 45 | 0.0913 | 30 | 2 | -0.0057 | 11 | 1 | -0.1159 | 46 | 2 |
| 46 | 0.1678 | 43 | 2 | -0.1294 | 36 | 2 | -0.0836 | 35 | 2 |
| 47 | 0.2042 | 50 | 3 | -0.3884 | 68 | 3 | 0.2040 | 2 | 1 |
| 48 | -0.0202 | 5 | 1 | 0.0197 | 8 | 1 | 0.0201 | 6 | 1 |
| 49 | 0.3947 | 64 | 3 | -0.4246 | 71 | 4 | -0.4589 | 79 | 4 |
| 50 | 0.0863 | 28 | 2 | -0.0651 | 23 | 1 | -0.0979 | 42 | 2 |
| 51 | 0.0724 | 26 | 2 | -0.1334 | 37 | 2 | -0.0302 | 24 | 2 |
| 52 | 0.1155 | 32 | 2 | -0.3159 | 61 | 3 | -0.0776 | 31 | 2 |
| 53 | 0.0661 | 24 | 2 | -0.0733 | 24 | 2 | -0.0464 | 25 | 2 |
| 54 | 0.0251 | 17 | 1 | 0.0445 | 3 | 1 | -0.0218 | 20 | 1 |
| 55 | -0.0596 | 2 | 1 | 0.1714 | 1 | 1 | 0.0824 | 3 | 1 |
| 61 | 1.2386 | 88 | 4 | -0.9607 | 86 | 4 | -0.9283 | 85 | 4 |
| 63 | 0.0235 | 16 | 1 | -0.0584 | 22 | 1 | -0.0204 | 17 | 1 |
| 64 | 0.6115 | 72 | 4 | -0.2913 | 56 | 3 | -0.5241 | 82 | 4 |
| 66 | 0.6943 | 77 | 4 | -0.5651 | 80 | 4 | -0.3578 | 70 | 4 |
| 67 | 0.0177 | 13 | 1 | 0.0026 | 9 | 1 | 0.0085 | 9 | 1 |
| 68 | 0.3068 | 58 | 3 | -0.5159 | 77 | 4 | -0.1893 | 59 | 3 |

### TABLE 6.5 (continued)
### CHANGES IN UNEMPLOYMENT RATE, PROFITS AND PERSONAL INCOME IN THE AQCRs UNDER STRATEGY 3

| AQCR | Increase in Unemployment Rate | Rank | Q | % Change in Profit | Rank | Q | % Change in Personal Income | Rank | Q |
|---|---|---|---|---|---|---|---|---|---|
| 69 | 0.0180 | 14 | 1 | -0.0925 | 26 | 2 | -0.0206 | 18 | 1 |
| 70 | 0.2036 | 48 | 3 | -0.1702 | 49 | 3 | -0.1742 | 55 | 3 |
| 71 | 0.0473 | 19 | 1 | 0.0246 | 7 | 1 | -0.0530 | 26 | 2 |
| 72 | 0.8108 | 81 | 4 | -0.3190 | 62 | 3 | -0.4343 | 76 | 4 |
| 73 | 0.1897 | 45 | 2 | -0.1001 | 29 | 2 | -0.1212 | 49 | 3 |
| 74 | -0.1650 | 1 | 1 | -0.0088 | 12 | 1 | 0.2035 | 1 | 1 |
| 75 | 2.3466 | 90 | 4 | -1.3073 | 87 | 4 | -1.0372 | 88 | 4 |
| 76 | 2.2496 | 89 | 4 | -2.0409 | 91 | 4 | -1.2092 | 89 | 4 |
| 77 | 0.2262 | 52 | 3 | -0.1377 | 40 | 2 | -0.1780 | 56 | 3 |
| 78 | 0.1709 | 44 | 2 | -0.3387 | 65 | 3 | -0.0963 | 40 | 2 |
| 80 | 0.6056 | 71 | 4 | -0.7389 | 84 | 4 | -0.9520 | 87 | 4 |
| 81 | 0.1548 | 41 | 2 | -0.1544 | 45 | 2 | -0.1144 | 44 | 2 |
| 82 | 0.3215 | 60 | 3 | -0.1590 | 46 | 2 | -0.1584 | 53 | 3 |
| 83 | 0.1169 | 33 | 2 | -0.1931 | 50 | 3 | -0.0947 | 39 | 2 |
| 84 | 0.7427 | 79 | 4 | -0.4437 | 72 | 4 | -0.4543 | 78 | 4 |
| 85 | 0.2981 | 57 | 3 | -0.4128 | 70 | 4 | -0.1877 | 58 | 3 |
| 86 | 0.0051 | 10 | 1 | -0.0205 | 15 | 1 | -0.0069 | 14 | 1 |
| 87 | 0.3630 | 62 | 3 | -0.3195 | 63 | 3 | -0.2023 | 60 | 3 |
| 88 | 0.0526 | 20 | 1 | -0.0136 | 13 | 1 | -0.0800 | 33 | 2 |
| 89 | 0.6218 | 74 | 4 | -0.8602 | 85 | 4 | -0.4271 | 75 | 4 |
| 90 | 0.3399 | 61 | 3 | -0.2903 | 55 | 3 | -0.3757 | 71 | 4 |
| 91 | 0.2039 | 49 | 3 | -0.1421 | 43 | 2 | -0.0852 | 36 | 2 |
| 92 | 0.1078 | 31 | 2 | -0.3080 | 59 | 3 | -0.0700 | 29 | 2 |
| 93 | 0.2955 | 56 | 3 | -0.1542 | 44 | 2 | -0.0977 | 41 | 2 |
| 94 | 0.7491 | 80 | 4 | -0.5197 | 78 | 4 | -0.5721 | 83 | 4 |
| 95 | 0.6990 | 78 | 4 | -0.1678 | 48 | 3 | -0.3477 | 68 | 3 |
| 96 | -0.0035 | 8 | 1 | -0.0046 | 10 | 1 | 0.0034 | 11 | 1 |
| 97 | 0.8587 | 83 | 4 | -0.3905 | 69 | 3 | -0.4403 | 77 | 4 |
| 98 | 0.2542 | 53 | 3 | -0.1595 | 47 | 3 | -0.2361 | 63 | 3 |
| 99 | -0.0287 | 4 | 1 | 0.0511 | 2 | 1 | 0.0396 | 4 | 1 |
| 100 | 0.4812 | 69 | 3 | -0.2178 | 51 | 3 | -0.2279 | 62 | 3 |

median for each indicator under each of the three policies is presented below in Table 6.6.

TABLE 6.6

Median Values of the Distributions of the Changes in Unemployment Rate, Percentage Changes in Profits and Personal Income in the Three Strategies*

| | Strategy 1 (Industry Pays) | Strategy 2 (Hands Off) | Strategy 3 (Cost Sharing) |
|---|---|---|---|
| Increase in Unemployment Rate | 0.5455 | 0.3654 | 0.2102 |
| Percentage Decrease in Profits of Manufacturing Industries | 0.6667 | 0.2885 | 0.2000 |
| Percentage Decrease in Personal Income | 0.4286 | 0.2035 | 0.1557 |

*In Strategy 1, high emission industries are assumed to absorb the entire cost of control. In Strategy 2, high emission industries will pass on part of the control costs as a 0.4 percent price increase to the consumer. In Strategy 3, it is assumed that the Federal government will raise, by a special tax to subsidize the high emission industries by an amount equal to 50 percent of the control costs not covered by the price increase in Strategy 2. In all three strategies, it is further assumed that electric utilities will pass on their control costs to the consumers as a price increase.

The trend in the three indicators presented in this table tend to be consistent with the analysis of changes in unemployment rate presented in the previous section. The profits of manufacturing industries show the highest sensitivity among the three variables.

A variety of other economic indicators that reflect the impact of alternative strategies are printed out in the simulation as shown in Table 6.1.

### 6.5 Total Net Effects of Three Alternative Strategies for 91 AQCRs

This section presents some evidence on the effects of the three air pollution control strategies totalled for 91 AQCRs. A number of caveats are in order.

First, the APCO Model System, as it now stands, is a cross-sectional regional model; consequently, its strength lies in its assessment of geographical patterns of change in the AQCRs. Its estimates of aggregate changes are less reliable. Second, the 91 AQCRs used in the model cover the greater portion of the economic activity in the nation, but not all. Finally, the model system does not capture the dynamic effects and macro effects that only a national model can handle. Consequently, the interpretation presented below must be viewed with a dose of caution.

Some evidence on the overall impact of air pollution control and the effect of incidence policy thereon is presented in Table 6.7, which

## TABLE 6.7

### NET EFFECTS OF THREE ALTERNATIVE STRATEGIES ON 91 AQCRS*

| Changes in Key Indicators | Strategy 1 | | Strategy 2 | | Strategy 3 | |
|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % |
| Profits in Manufacturing Industries | -$ 345 (million) | - 0.47 | -$ 396 (million) | -0.54 | -$ 429 (million) | -0.59 |
| Regional Personal Income | -$ 841 (million) | - 0.21 | -$ 1,123 (million) | -0.28 | -$ 1,279 (million) | -0.32 |
| Employment** | -146,000 | - 0.43 | -171,000 | -0.48 | -185,000 | -0.50 |

***For a detailed description of the three strategies, see page 94 or Chapter 5.**

****This indicates an increment of base unemployment rate of 3.45 to 3.88, 3.94 and 3.95, respectively.**

presents totals for the 91 AQCRs in the simulation.* The table reflects a decline in economic activity regardless of the incidence policy pursued. Under the "Hands Off" strategy, which is in many ways the most plausible Federal posture, the unemployment rate for the 91 regions increases from 3.45 percent to 3.93 percent, personal income declines by 0.28 percent and profits fall by 0.54 percent.

Somewhat more surprising at first blush are the results as one moves from a strategy which localizes the incidence of control (Strategy 1 -- Industry Pays) costs to one which spreads the incidence over the whole of the nation (Strategy 3 -- Cost Sharing). From an aggregative point of view, Table 6.7 shows that the total effect of control is minimized if steps are taken to see that the sources incurring air pollution control costs bear their full incidence. This can be seen by comparing the percentage changes in these three tables. Note that those in the declines for Strategy 1 are uniformly smaller than those for Strategy 2, which are themselves uniformly smaller than those for Strategy 3. One might tentatively conclude, therefore, that from a purely aggregative standpoint, policies which spread the incidence of control costs tend to increase the aggregative negative economic effects of air pollution control. If one were willing to extrapolate these findings to the nation, what this implies is that cost sharing financed by increases in the personal income tax, could actually make unemployment worse rather than better. This result is not unreasonable since an increase in personal income taxes for the purpose of financing subsidies (which are not government purchases of goods and services) reduces final demand by the amount of the marginal propensity to consume times the tax increase.

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*The 100 AQCRs for which data was corrected in this study, only 91 AQCRs have been included in the model estimation and simulation. For the remaining nine AQCRs, some of the economic data was not available. These AQCRs are: Hartford, Connecticut; Cheyenne, Wyoming; Anchorage, Alaska; Burlington, Vermont; San Juan, Puerto Rico; Virgin Islands; Anderson, Indiana; Flint, Michigan; and Worcester, Massachusetts.

The view of cost sharing which emerges when results for individual regions are considered is thus quite different from that which emerges from solely aggregative considerations. While cost sharing results in overall worsened economic performance, the number of regions severely affected adversely by air pollution control is reduced. There appears to be a policy trade-off to be made. The policy-maker must decide whether he wishes to have a few regions experience considerable adverse effects while maintaining good overall economic performance, or slightly reduce overall performance so that a few regions may be spared severe hardship. It should be remembered that the results that support this finding presuppose a particular cost sharing scheme. It is not the only one which could be undertaken.

These results on differential regional impact are suggestive in many veins, but one in particular deserves comment. Some regions evidently have an economic capacity to meet more rigorous emission and air quality standards than do others.

## 6.6 Concluding Comments

In conclusion, it must be observed that the trial simulation of three strategies and the interpretation of results has demonstrated to a limited degree the operational nature and strategy assessment potential of the model system. Surely, what has been done here is but scratching the surface of the utilization potential of the model system. What has been done, however, clearly points to the view of the regional economy and environmental system (quality levels) as interrelated systems and that control activities affect profoundly in many dimensions economic activity. However, these economy-environment relationships are more complex than evident in this demonstration. This suggests the need for further efforts in model utilization, sensitivity testing, model system refinement as appropriate, and more up to date information.

The fundamental question of incidence of economic burden of control policies and the caveats expressed in this interpretation do certainly warrant further exploration of the model utilization.

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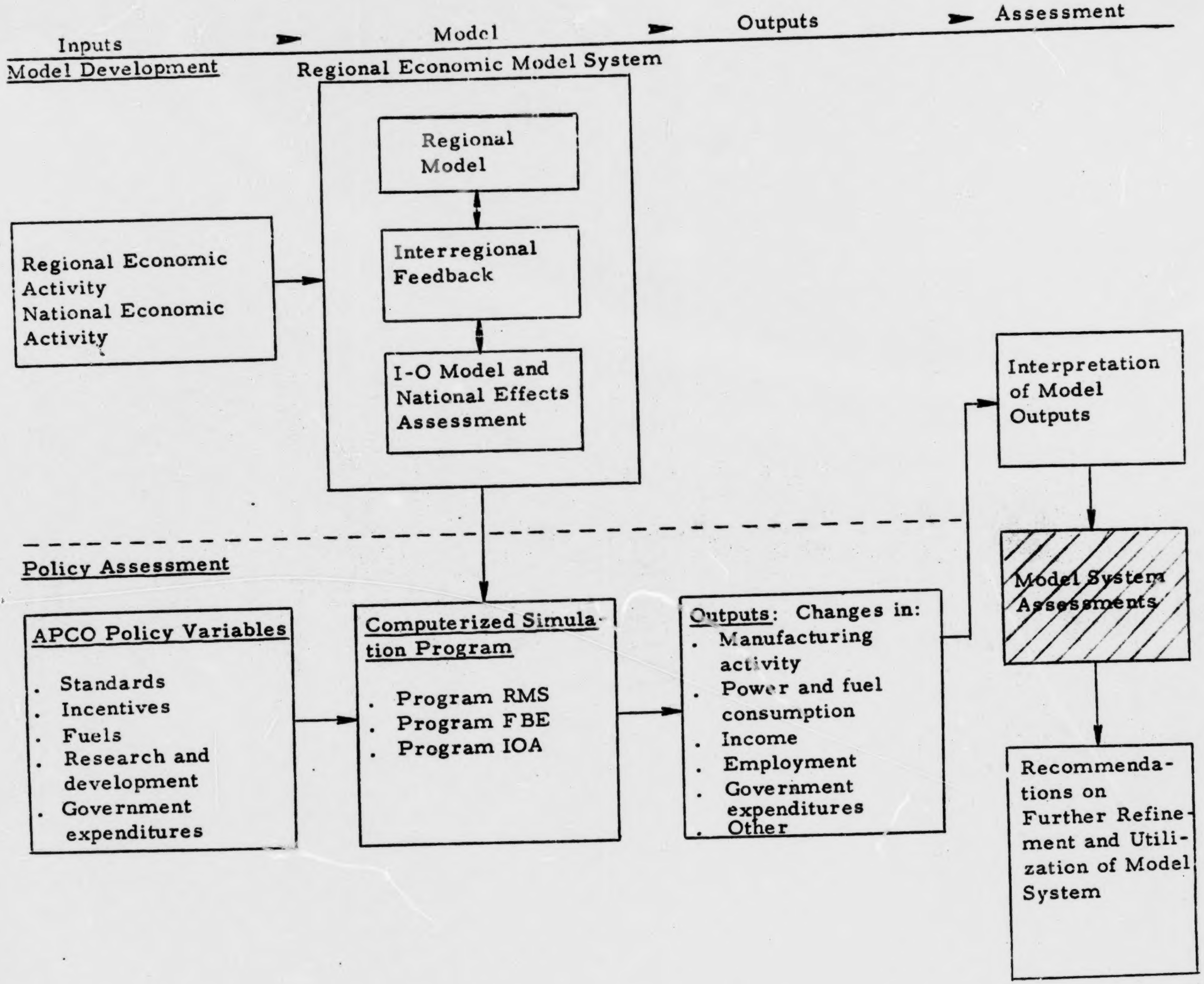
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Model Development
Regional Economic Model System
Regional Economic Activity
National Economic Activity
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Interpretation of Model Outputs
Model System Assessments
Policy Assessment
APCO Policy Variables
. Standards
. Incentives
. Fuels
. Research and development
. Government expenditures
Computerized Simulation Program
. Program RMS
. Program FBE
. Program IOA
Outputs: Changes in:
. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other
Recommendations on Further Refinement and Utilization of Model System

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# 7.0 AN ASSESSMENT OF THE APCO REGIONAL ECONOMIC MODEL SYSTEM: PROMISES AND PITFALLS

The objective of the effort described in previous chapters was to develop and demonstrate the use of an operational analytical tool for assessing the complex and far-reaching economic effects of air pollution abatement strategies.

First in St. Louis, then in 31 AQCRs and now in 100 AQCRs, such an operational model amenable to some policy assessment was developed. In other words, the elements of the economic system were defined; the air pollution control tools identified in this context; the equations set up; the relations established which determine the values of the elements; that is, the economic system described; effects of certain alternative strategies estimated, and the properties of this "solution" investigated and assessed. The logical question at this stage is: How good or useful is the Regional Economic Model System?

An unambiguous answer to this question is not possible at this stage. It is true that the use of the Regional Model System as a tool to assess these strategies has been demonstrated; this is no mean feat considering the complexity of the economic system modelled. Further, the simulations showed considerable sensitivity of the model system and the complex and profound interrelationships between control policies and various facets of the regional economies. However, this demonstration has explored only a limited portion of the utilization potential of the model systems. Judgments on the utilization potential of the model system have to be necessarily tentative.

The model system, however, can be assessed from a set of more general criteria. The three parts of the Regional Model System -- Model Structure, Data and Simulation -- can be evaluated by the following five criteria.

1. Model Scope: What sorts of control policies are covered by the model structure? Which are excluded? How does this policy coverage of the model affect its relevance as an ongoing policy assessment tool?

2. Model Structure: Given the policy scope, how efficiently is the model structured? How comprehensible is the model structure? Is the model system a "black box" or a "white box"?* How extravagant is the model in terms of data requirements?

3. Model Sensitivity and Accuracy: How readily manipulable is the model? How sensitive is it to policy inputs? How accurately is the model system representing economic reality?

4. Data Limitations: What are the quality and currency of the data used in the model? What additional data would improve model scope and performance?

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*A black box model is one whose structure is not clear but defined in terms of inputs or outputs and can be contrasted with "white box" models whose structure is "transparent."

5. Efficiency of Simulation Program: How efficiently is the simulation program assembled? Is the program extravagant of processing time? How user oriented is the program?

Model Scope

The range of policies to which the Regional Model System is designed for was described in Chapter 5 and is quite large. However, there are two major limitations in scope. First, the Regional Model System in its present stage of development does not fully incorporate the interdependency between the economic system and environmental quality. Since air pollution is a by-product of economic activity, the level of total emissions is directly related to the level of economic growth (say GNP), geographic distribution of the growth and the industrial composition of the economy. The present model system provides only an estimate of economic effects, with given air pollution levels (before and after the control is instituted).

A feasible approach for addressing this limitation would be to build into the model system relationships between unit levels of economic activity by industrial sector and emission levels and control costs. In this manner, as economic activity increases, emission levels and control costs will also increase and the effects of such emission and cost increases on economic activity can be computed. Thus, a more interdependent economic environmental regional model system can be developed.

The second limitation of the model system is its cross-sectional and static structure. In its current stage, the model system traces the cross-sectional reallocation of economic activity among the ACQRs attendant on control strategies pursued in the 305(a) Report. Thus, it is possible to identify which AQCRs are affected adversely by the control policies. But the overall effects of control on different industrial regions and their varying growth rates in the future are not captured now. A dynamic model, if developed, would assess, for instance, a "practical timetable" for control of stationary emissions, the minimal economic dislocations, demand for control devices, etc., over time and be a realistic aid to important issues likely to confront policy-makers in the next several years.

### Model Structure

The Regional Economic Model System must be viewed as a well structured regional model with elaborate sectoring of high emission industries and careful integration of regional economic concepts. The sectoring is elaborate enough to be sensitive to a wide range of high emission industries and electric power industry -- no mean achievement. Given its complexity, the operationability of the model is worthy of note. Furthermore, the equations all conform to a priori expectations of theory.

As is to be expected, this model's structure provides room for improvement in many different ways.

First, the treatment of interregional effects in the model leaves something to be desired. The use of the locational quotient or regional market share matrix assumes a fixed regional distribution of economic activity -- over time an unrealistic assumption.

Second, the nonavailability of a national macro model limits the estimation of national effects to the structural changes obtainable from the I-O model. The latter represents only a partial statement of national effects. This drawback can be addressed only by one of the alternatives proposed at the end of Chapter 4.

Third, there is one important kind of variable not explicitly treated in the model -- price variables. The model itself thus makes no forecasts of changes in prices occasioned by air pollution control, but rather requires such information as input information. Since one of the chief concerns about air pollution control is that it will raise prices, it would be desirable to modify the model so that price effects of air pollution control are predicted as well.

While the model gives generally good coverage to important variables of regional economic activity, it is deficient in geographical scope for national economic effects assessment. Although the model is large and covers all major urban AQCRs, only about 65 percent of

GNP is accounted for by output from these regions. There is thus a large portion of economic activity and impacts of air pollution thereon left unaccounted for by the model.

Fourth, the method by which the model treats air pollution control costs and benefits is restrictive. Such information now is treated as input information into the model. That is, the model user must translate his policies into control costs and control benefits, feed these values into the economic model system, and the computer does the rest. Or to put it more technically, control costs and benefits are treated as exogenous variables in the system (see Chapter 5). In fact, control costs and benefits ought to be endogenous in the system since control costs depend in major measure on the level of economic activity, which indicators are themselves the key endogenous variables of the model. In like fashion, damages reductions (or benefits) depend upon changes in the level of economic activity and control activity. Treating these variables as exogenous is thus likely to result in faulty predictions of the net effect of air pollution control of as yet unknown extent.

The remedy for this particular defect of structure is the same as proposed earlier to incorporate interdependencies between the economy and the environment.

## Model Sensitivity and Accuracy

The model system appears to be sensitive to the range of strategies tested. The differences in key economic indicators among the various AQCRs are encouragingly significant. The same assertion, however, cannot be made about effects totalled over the AQCRs. In any event, further sensitivity testing is warranted before any assessment in this regard can be made.

As yet, no thorough test of model accuracy has been conducted since the data on which model estimation was based are the only data CONSAD has assembled. For a true model test, it is necessary to see whether the model accurately predicts data that has not been used in estimating the model. Insofar as accuracy of the model in explaining sample data itself is concerned, however, the following points should be made:

- By themselves, individual equations of the model appear to satisfactorily explain model data. The percentage of variation accounted for in the equations are, on the average, about 90 percent.
- Comparisons of actual with predicted values for a few AQCRs suggest that the model does reasonably well in predicting values for industrial cities, but not so well for non-industrial AQCRs like Washington, D. C.

More testing will be needed, however, to adequately assess the model system's accuracy and to pinpoint the source of any inaccuracies for elimination.

### Data Limitations

This model system uses a large mass of data for 1967 (see Appendix E). The parameters of the model reflect 1967 situation and the continued use of the model calls for an updating of these data or the use of forecast data from other sources such as the OBE data for 50 AQCRs.

Five year average data on control costs have been used from the 305(a) Report of 1970. Year by year data for 1971-75 would have been more realistic.

Benefit data used in the model is very much in the nature of "informed judgment". Alternative levels of the benefit estimates or better estimates would improve the outputs from the model.

### Simulation

As yet, little experience has been had with the use of the model system. It can be said with some confidence that the model simulation program works, which, for a model of the size and complexity of this one, is no small achievement. Also, it is efficient in terms of computer processing time. Furthermore, the model and its simulation program appear to be sufficiently flexible to permit investigation of a wide range of policy alternatives.

There are, however, two drawbacks in the manner in which the simulation program is assembled. First, the model, including its simulation program, is very large. As a consequence, it is difficult to understand and, therefore, less than simple to manipulate by the general user for policy evaluation purposes other than those expressly provided for in the simulation program.

Second, there is a non-linear component for which there is no "exact solution." Therefore, an interative algorithm -- an extended Newton's method*-- has been applied. The accuracy of this method is dependent upon the number of iterations involved in the computer runs and process of convergence of the system. This aspect calls for a further testing of this algorithm for errors due to aborted convergence.

Third, at the present stage, only a limited number of strategies has been tested. It is more plausible that additional strategies and hence nature of inputs, be applied to improve the use potential of this simulation program.

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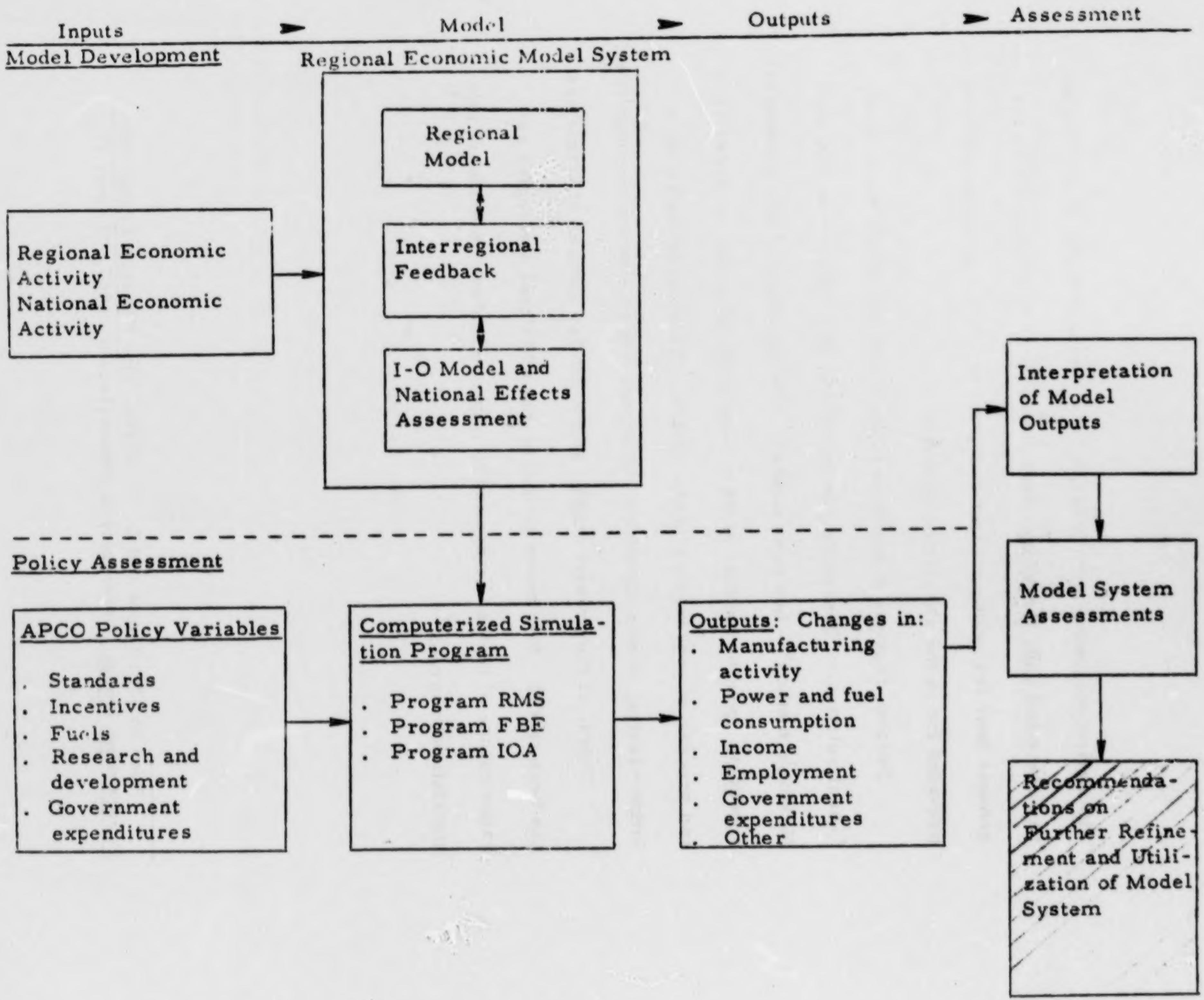
*See M. K. Evans and L. R. Klein, The Wharton Econometric Forecasting Model, University of Pennsylvania, 1967, Chapter IV.


Inputs
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Regional Economic Activity
National Economic Activity
Regional Model
Interregional Feedback
I-O Model and National Effects Assessment
Interpretation of Model Outputs
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. Manufacturing activity
. Power and fuel consumption
. Income
. Employment
. Government expenditures
. Other

# 8.0 REFINEMENT AND UTILIZATION OF THE APCO ECONOMIC MODEL SYSTEM: RECOMMENDATIONS

This report covers a great deal of material in fairly minute detail. Much of the material concerns what has been done over the past three years. It was clear at the outset that CONSAD's contribution to the Regional Air Pollution Analysis (RAPA) would be to develop and demonstrate the use of a workable analytical tool, to assess the economic effects of various abatement strategies in the AQCRs.

The model system has been developed and demonstrated in a limited manner for three strategies.

In describing the model system and the uses to which it has been put to date, CONSAD has attempted to alert the potential user to deficiencies in the model system, as well as to indicate its achievements. This chapter is different in character since it deals not with what is past, but rather the potential of the model system for future assessment of economic effects of air pollution control strategies. In a nutshell, the key question which this chapter addresses itself is "Where, if anywhere, should APCO go from here?"

In the process of describing the model system as it stands and in evaluating the potential of a program of model refinement and utilization, a number of ideas have been expressed. It has been suggested, for example, that (1) the model be employed, if possible, for national economic effects assessment, (2) that the model be applied to assessing alternative timing of implementation policies, (3) that the model be used to predict the effects of different strategies for setting secondary ambient air quality standards and performance standards for new sources, (4) that the model be applied to the problem of forecasting pollution emissions, and (5) that the effect of ambient air quality improvements on the productivity of labor and capital be investigated. There is evidently no dearth of interesting and important questions which could be posed for the model system, some of which the model is now fully capable of evaluating and others of which the model could be refined to handle. Indeed, what is needed is an orderly plan of attack.

Based upon its own evaluation of the issues and possibilities raised in this report, CONSAD has identified the following four recommendations for maximum utilization of the economic model system.

## Recommendation 1: Further Utilization of the APCO Economic Model System

CONSAD recommends that an in-depth utilization of the APCO Economic Model System developed in the current year be carried out. The further utilization of the model system will serve three purposes. First, it will follow-up on the preliminary analyses of the three strategies and their variations to assess in-depth the economic effects of various strategies. Second, it will incorporate data that has become available since the 1967 economic data used in the model development. In this manner, the model system will be more honed in. Third, the utilization of the model system with new data will identify potential areas for model refinement, sensitivity analysis, and further applications of the model. Among other possible applications could be potential opportunity to extend the model to assess the effects of water quality and solid waste control strategies.

### Recommendation 2: Sensitivity Analysis and Refinement of the Model System

With the experience gained from the in-depth utilization of the model system, CONSAD recommends a sensitivity analysis of the model system. The model system should be refined and modified accordingly, to remove any deficiencies insofar as possible. As these modifications are carried out, the effort should be directed to develop a broad adaptable operational tool. Therefore, a generalized computer simulation program should be developed for the refined model system.

### Recommendation 3: Expanded National Model Study

The model system, in its current form, is largely "comparative static" and "regional." CONSAD recommends that "dynamic" and "national" aspects of the economic impacts of air pollution control needs to be built in. Ideally, this can be accomplished by links between the cross-sectional regional model and a time-series national model, with interaction between economic and environment systems to be integrated in the model system.

There are a number of ways, however, in which one might go about attaining the ideal. CONSAD has identified three alternatives which it believes to be worthy of further study:

- One might try to make do with the Economic Model System as it is currently structured (or as refined if Recommendation 2 is pursued), since the model encompasses approximately 65 percent of the nation's economic activity. This percentage could be increased by increasing the number of regions included in the model.
- An existing national economic model (e.g., Klein-Goldberger, Michigan) might be modified and adopted for purposes of strategy assessment.
- A new model could be built expressly for the purpose of assessing national effects of national air pollution control strategies.

# APPENDIX A

# A MODEL TO ASSESS THE ECONOMIC EFFECTS OF AIR POLLUTION ABATEMENT IN ST. LOUIS AQCR

# (PHASE I)

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# Appendix A: A Model to Assess the Economic Effects of Air Pollution Abatement in the St. Louis AQCR (Phase I)

The purpose of this appendix is to describe an econometric model which simulates the basic economic structure of an Air Quality Control Region (AQCR) for testing the impacts of air pollution control policy in that AQCR. The model will be specified for the St. Louis Standard Metropolitan Statistical Area (SMSA). The model will be presented in its abstract form in order to illustrate the theoretical background and implications of the entire equation system.

A comparison of the development of regional models with several advanced models at the national level* reveals that the existing econometric models at a regional level are still few -- their scope much more limited and the in results less sophisticated. The relative backwardness of the regional model stem from three reasons.

First, at the national level, good time series data have been available for all major economic variables and other variables, such as capital stock are even published as the result of theoretical inquiry. But at the regional level -- either state or SMSA -- data are unreliable and unavailable, especially in a continuous time series form.

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*For example, Klein, L. R., "A Postwar Quarterly Model," Models of Income Determination, Studies in Income and Wealth, Vol. 28, Princeton, New Jersey, Princeton University Press, 1964; Klein, L. R., and Goldberger, A. S., An Econometric Model of the United States, 1929-1952, Amsterdam, North-Holland, 1955; Suits, Daniel B., "Forecasting and Analysis with an Econometric Model," American Economic Review, Vol. 52, March, 1962, pp. 104-132; and Dusenberry, J. S., Fromm, G., Klein, L. R., and Kay, E. (eds.), The Brookings Quarterly Econometric Model of the United States, 1965.

Second, econometricians began the development of their models at the national level. From time to time, different equations and theories have been tested with the same base of data in a well-defined economy, say the United States. By repetition of tests and the accumulation of experience, models calibrated to good theoretical structures are now in sight. On the other hand, regional models always deal with different geographic units. Beyond the uniqueness of data, suggested by location theory, geographic and cultural environment and socio-economic structures may differ from region to region.

Third, theoretically speaking, macro-economic models are usually based on well-established economic theory in their formulation. However, at the regional level, economic base theory, location theory, gravity concepts, migration theory, etc. (especially the concept of "distance" emphasized by regional scientists for some time), are much harder to integrate into an overall hierarchical system.

In spite of such shortcomings, some notable regional models have been recently estimated. For example, Bell estimated a Massachusetts model. An Alaskan model by Tuck, a Puerto Rico model by Lakshmanan and Lo, a Northeast Corridor model by Crow, a Michigan model by Suits, a Philadelphia SMSA model by Glickman, and a Hyogen-ken model in Japan by Kaneko can be indicated.* Klein** recently suggested a general strategy in building regional econometric models to link with national models.

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*See Frederick W. Bell, "An Econometric Forecasting Model for a Region," Journal of Regional Science, Vol. 7, No. 2, 1967; B. H. Tuck, An Aggregate Income Model of a Semi-Autonomous Alaskan Economy, Anchorage, Federal Field Development Committee for Development Planning, 1967; T. R. Lakshmanan and Fu-chen Lo, A Regional Growth Model of Puerto Rico: An Analysis of Municipio Growth Patterns and Public Investments, Pittsburgh, Pa., CONSAD Research Corporation, September, 1970; Robert Crow, "Econometric Model of the Northeast Corridor," (mimeograph) MATHEMATICA, October, 1967; Daniel B. Suits, "Econometric Model of Michigan," (mimeograph), Research Seminar in Quantitative Economics of the University of Michigan; Norman J. Glickman, "An Annual Econometric Model of the Philadelphia SMSA, 1949-1966," (mimeograph), Ph. D. Dissertation, Department of Economics, University of Pennsylvania, November, 1968; Yukio Kaneka, "An Econometric Approach to Annual Forecast on Regional Economy by Local Government," Paper and Proceedings, The Second Far East Conference of Regional Science Association, 1965, University of Tokyo Press, Tokyo, 1967; pp. 119-144;

**Klein, L. R., "Econometric Analysis of the Tax Cut of 1964," (mimeograph), Department of Economics, University of Pennsylvania, 1967.

For the present study, the following characteristics in this model may be different from national models:

- national influence upon local economy,
- migration patterns,
- interregional commodity flows,
- interindustrial structure, and
- function of local government.

The details are presented formally below.

**Notation**

*$X$ = gross regional output

*$C$ = regional consumption

*$I$ = regional investment

*$E$ = regional export

*$M$ = regional import

*$G^L$ = local government expenditures

$G^F$ = federal government expenditures

$P_C^L$ = local consumption price index

*$Y$ = regional capital stock

$r$ = national interest rate

$\Pi$ = total regional profit or property income

$T_1^L$ = local direct taxes

*$T_2^L$ = local indirect taxes

*$T^F$ = taxes paid to federal government by the region

*$T^R$ = transfer payments

$D$ = depreciation on regional capital stock

$Q_i$ = regional gross output by industry i $(i = 1, \ldots, n)$

$Q_i^N$ = national gross output by industry i

$P_i$ = regional price of output i

$P_i^N$ = national price of output i

$\Pi_i$ = profit level of regional industry i

*$E_i$ = exports by regional industry i

GNP = gross national product

$O_i$ = domestic final demand for regional output i

$a_{ij}$ = input-output coefficient of local economy

W = wage bill

P = regional population

U = regional unemployment

*N = regional total employment

*$N_i$ = employment by regional industry i

$w_i$ = wage rate of regional industry i

*L = regional labor force

*$P^M$ = regional net migration

$N^F$ = regional female employment

$w^N$ = national wage rate

t = time period

## The Model Framework

The gross regional product can be first identified as an identity:

(1) $$X = C + I + E - M + G^L + G^F$$

Three of the variables on the right-hand side of this identity -- consumption, investment and export -- always have been emphasized in other regional growth models. These three variables determine the regional multiplier effect on regional growth through the Keynesian type multiplier-acceleration principle or regional export base theory. The government sector plays an important role in the regional economy and is, therefore, included in the regional model. It is classified into local and Federal components.

The consumption and investment function can be formulated as:

(2) $$\frac{C}{P_C^L} = f_2 \left(\frac{Y}{P_C^L}\right)$$

(3) $$I = f_3 (X, K_{t-1}, r, \Pi)$$

where the consumption function has been presented in real term as function of disposable income.

The regional disposable income identity is:

(4) $$Y = X - T_1^L - T_2^L - T^F + T^R - D,$$

that is, gross regional product after tax ($T_1^L$, $T_2^L$, $T^F$) and depreciation (D) of existing capital stock plus transfer payments ($T^R$). The investment function may be disaggregated into manufactures and nonmanufactures or even according to the sectoral structure. However, the general form of equation (3) should do.

It has been indicated that for a regional model, the export sector usually plays an important role, especially for a relatively small regional unit such as the St. Louis SMSA. Trade with the "rest-of-the-world" is the key to economic growth. Regional export may be strongly related with metropolitan's interindustrial structure. Thomassen,* Bell, Glickman, and Klein** link exports also with Gross National Product (GNP). However, it is important that the export sector be disaggregated, and that sectoral exports should be taken as a function of national sectoral output and of comparative sectoral prices between the region and the "rest-of-the-world." The reason is that the interindustrial structure of a large metropolitan area may be quite different from that at the national level. As suggested by location theory, regional resource endowments and other socio-economic characteristics determine the industrial structure of a local economic unit. Therefore, the use of a GNP trend is a less desirable indicator of external market demand than national outputs by industry. In general, regional sectoral output ($Q_i$) is a function of local interindustrial demand ($Q_i$, $j=1,\ldots,n$), national sectoral output ($Q^N$), comparative price ($\frac{p_i}{p_i^N}$), profit ($\Pi_i$), and regional output (x).

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*See H. Thomassen, "A Growth Model for a State," Southern Economic Journal, No. 24, 1957, pp. 123-139.

**Frederick W. Bell, Norman J. Glickman, and L. R. Klein, op. cit.

$$(5) \qquad Q_i = f_5 \left(Q_i, \ldots, Q_n, Q_i^N, \frac{p_i}{p_i^N}, \Pi_i, X\right) \qquad i = 1, \ldots, n$$

However, such a formulation may face a serious multicollinearity problem upon estimation. A possible solution to this problem is to separate (5) into two equations, namely, export demand and domestic demand. Noting that export data is unavailable, residual exports of the $i^{th}$ industry ($\hat{E}_i$) can be defined as:

$$(6) \qquad \hat{E}_i = Q_i - \sum_{j=1}^{n} a_{ij} Q_j - O_i \qquad i = 1, \ldots, n$$

where $O_i$ is domestic final demand of industry i. Equation (6) may be obtained from an output-input table, a technique that has been applied in the recent Brookings' model.* For these export-oriented industries, the residual export function will be:

$$(7) \qquad \hat{E}_i = f_7 \left(Q_i^N, \frac{p_i}{p_i^N}, \Pi_i\right) \qquad i = 1, \ldots, k, k+1, \ldots m$$

where the first k industries are high emission sources.

However, since there is some industry ($i = k+1, \ldots, n$) which has a small role in export, we can aggregate into one equation:

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*Dusenberry, J. S., et al., op. cit.

$$(8) \qquad \sum_{i=k+1}^{n} \hat{E}_i = \hat{E}_R$$

$$(9) \qquad \hat{E}_R = f_9 \left(GNP, \frac{P}{P^N}\right)$$

Imports may be divided into consumption goods ($M_C$) and industrial demand ($M_I$).

$$(10) \qquad M = M_C + M_I$$

$$(11) \qquad M_C = f_{11} \left(Y, \frac{P_C}{P_C^N}\right)$$

$$(12) \qquad M_I = f_{12} \left(X, \frac{P}{P^N}\right)$$

Equation (12) can be disaggregated according to export sectors, or equations (10), (11) and (12) can be aggregated into one equation:

$$(10') \qquad M = f \left(X, \frac{P}{P^N}\right).$$

The ability to estimate the import function is highly dependent upon availability of data and relations with other equations.

The government sector plays an important role in the regional economy, and must therefore be included in the regional model.

In most of the national models, government expenditures have been treated as exogenous.* Klein has strongly suggested to make them endogeneous at the regional level.* After a small modification of his proposal, we have:

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*The Brookings Model has allowed for endogeneous treatment. See Dusenberry, J. S., _et al._, _op. cit._; and Ando, A., Brown, E. C., and Adams, Jr., E. W., "Government Revenue and Expenditures."

(13) $$T_1^L = f_{13}(W, \Pi)$$

(14) $$T_2^L = f_{14}(X)$$

(15) $$T^F = f_{15}(W, \Pi)$$

(16) $$T^R = f_{16}(U, P)$$

(17) $$G^L = f_{17}(T_1^L + T_2^L, P)$$

where direct local taxation ($T_1^L$) and Federal tax ($T^F$) are functions of wage bill and profit; indirect local tax ($T_2^L$) is a function of regional output, while transfer payments ($T^R$) is a function of unemployment and population. Finally, local government expenditures ($G^L$) is a function of local taxation and population.

Through the multiplier effect, the mix of expenditures from private and public sectors (effective demand) determines gross regional product; by the same token, level of gross regional product determines the regional employment levels. From our last experience in the Economic Development Administration (EDA) labor force model,* the labor market behavior can be given by the following equations:

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*Klein, L. R., op. cit.

$$(18) \qquad N_i = f_{18}(Q_i, W_i, K_i) \qquad i = 1, \ldots, n$$

$$(19) \qquad L = f_{19}(\Sigma N_i, P, P^M, N^F, \ldots)$$

$$(20) \qquad P^M = f_{20}\left[P^M_{t-1}, \frac{W}{W^N} \left(\frac{N}{L}\right)_{t-1}\right]$$

$$(21) \qquad U = L - \sum_i N_i$$

Employment is a function of output, wage rate and capital stock; and labor force is determined by employment, population (P), migration ($P^M$) and female worker. While regional migrations are determined by past figures ($P^M_{t-1}$), wage difference ($\frac{W}{W^N}$) and employment-labor force $(\frac{N}{L})_{t-1}$. Finally, the differences between labor force and employment determines regional unemployment.

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*CONSAD Research Corporation, A Study of the Effects of Public Investment, Pittsburgh, Pa., 1968.

## The St. Louis Model

Except for the income-determination block, the model is recursive in nature. GNP is expressed in terms of national income by sectors (two-digit SIC in manufacturing industries) and, as external market demand, determines the level of exports from the St. Louis SMSA. The exports then determine the output levels of St. Louis manufacturing sectors and, hence, their import demands. By the production functions, once output level is given, capital share (profit) can be obtained (since the Cobb-Douglas production function is assumed). Investments are a function of profit and previous capital stocks. After adjustment for depreciation, capital stock is given by the following accounting relationship:

$$K_t = K_{t-1} + I_t - dK_t$$

where I and K are investment and capital, respectively, and d is depreciation rate. Given output level and capital stock, the employment level also can be obtained through the production function.

On the other hand, given exports, imports, investment, and government expenditures (the latter is a function of tax revenue), regional income and consumption expenditures are determined simultaneously. As to income determination, two types of theories are emphasized in the Keynesian type of model -- the multiplier-acceleration principle which is based on the propensity to consume, and the economic-base

Finally, non-manufacturing employment level is a function of non-manufacturing income. Labor force is then determined by total employment, national unemployment rate, and migration. The difference between labor force and total employment determines local unemployment. Because the electric-power industry has been considered a major pollutant in the St. Louis SMSA, electric-power demand functions have also been estimated.

The disaggregation of manufacturing industries into two-digit SIC levels requires further explanation. There were three major reasons for disaggregation: first, interindustrial structur at the regional level may be quite different from that at the national level. Second, the present model is designed to measure the economic impacts of air pollution control, and it is more realistic to observe the impact for each major manufacturing industry at the two-digit SIC level than to do so for the manufacturing industry as a whole. Third, measurement of exports, as emphasized by economic-base theory, requires sectoral disaggregation.

However, in the St. Louis economy, because certain two-digit manufacturing industries either are too small in scale or lack sufficient data, only 11 two-digit SIC industries were so isolated; and the manufacturing industries other than these 11 have been aggregated as "other manufacturing industry." The final 12 groups are as follows:

- SIC 20 - Food and kindred products,
- SIC 26 - Paper and allied products,
- SIC 27 - Printing and publishing,
- SIC 28 - Chemicals and allied products,
- SIC 29 - Petroleum and coal products,
- SIC 32 - Stone, clay and glass products,
- SIC 33 - Primary metal industries,
- SIC 34 - Fabricated metal products,
- SIC 35 - Machinery, except electrical
- SIC 36 - Electrical machinery,
- SIC 37 - Transportation equipment, and
- Other manufacturing - Including tobacco products (SIC 21), textile mill products (SIC 22), apparel and related products (SIC 23), lumber and wood products (SIC 24), furniture and fixtures (SIC 25), rubber and plastics (SIC 30), leather products (SIC 31), instruments and related products (SIC 38), and miscellaneous manufacturing (SIC 39).

The Variables of the St. Louis Model

$Y_{Nit}$ = **national income by sector i ($ million) at time t**

$E_{it}$ = **export by industry i ($ million) at time t**

$V_{it}$ = **value added by industry i ($ million) at time t**

$M_{it}$ = import by industry i ($ million) at time t

$N_{it}$ = employment by industry i (1000 employees) at time t

$K_{it}$ = capital stock of industry i (million dollars) at time t

$I_{it}$ = investment by industry i ($ million) at time t

$\Pi_{it}$ = capital share of value added or profit by industry i ($ million) at time t

$Q_{it}$ = electric power demand by industry i (1000 kilowatt hours) at time t

For the above variables:

$i$ = 20, 26, 27, 28, 29, 32, 33, 34, 35, 36, 37, and other manufactures. (These SIC numbers identify the 12 manufacturing sectors of the model)

$P_{Ni}$ = industrial commodity price index (1957-59 = 1.00)

$T_t$ = local tax revenue ($ million) at time t

$G_t$ = local government expenditure ($ million) at time t

$C_t$ = consumption ($ million) at time t

$Y^*_t$ $(\equiv C + \Sigma I_i + \Sigma E_i - \Sigma M_i + G)$ = regional expenditure ($ million) at time t

$Y_t$ = regional income ($ million) at time t

$\overline{N}_t$ = employment by industries other than manufacturing industries (100 employees) at time t

$N_t$ $(\equiv \Sigma N_i + \overline{N})$ = total employment

$L_t$ = total labor force

$u_t^N$ = national unemployment rate

$U_t$ = unemployment

$u_t$ = local unemployment rate

$Q_{ct}$ = electric power demand for residential use at time t (1000 kilowatt hrs)

$\overline{Q}_t$ = electric power demand for non-manufacturing industries at time t (1000 kilowatt hrs.)

t = time period (1954 = 0, 1955 = 1, . . . , 1966 = 12)

$w_i$ = wage per man-year by industry i (1000 dollars)

## Estimation of the Model

The general form of the export function will be:

$$(1) \qquad E_i = a_i + b_i Y_{Nit}$$

The results of estimation are:

| Equation Number | Industry Code | $a_i$ | $b_i$ | $R^2$ | Durbin-Watson Statistic |
|---|---|---|---|---|---|
| (1.1) | SIC 20 | 244.585<br>(45.371) | .0284<br>(.000366) | .832 | 1.713 |
| (1.2) | SIC 26 | 27.688<br>(4.163) | .00663<br>(.000861) | .830 | 1.697 |
| (1.3) | SIC 27 | 10.998<br>(7.128) | .0152<br>(.00104) | .947 | .534 |
| (1.4) | SIC 28 | - 4.462<br>(22.090) | .0664<br>(.00230) | .986 | 2.295 |
| (1.5) | SIC 29 | -344.071<br>(86.110) | .124<br>(.0183) | .789 | 2.55 |
| (1.6) | SIC 32 | 21.522<br>(10.528) | .0151<br>(.00222) | .791 | .772 |
| (1.7) | SIC 33 | -144.539<br>(83.865) | .0435<br>(.00716) | .750 | 2.218 |
| (1.8) | SIC 34 | 55.472<br>(12.206) | .0155<br>(.00136) | .915 | 2.064 |
| (1.9) | SIC 35 | 93.853<br>(7.792) | .0105<br>(.000574) | .965 | 2.105 |
| (1.10) | SIC 36 | 141.997<br>(18.689) | .00539<br>(.00169) | .435 | 1.079 |

(continued)

| Equation Number | Industry Code | $a_i$ | $b_i$ | $R^2$ | Durbin-Watson Statistic |
|---|---|---|---|---|---|
| (1.11) | SIC 37 | -468.752<br>(88.511) | .130<br>(.00945) | .940 | 1.812 |
| (1.12) | Other Manu. | 230.314<br>(19.383) | 0.03181<br>(.00053) | .747 | 2.517 |
| All Manufacturing Ind. | | -176.337<br>(181.595) | 29.527<br>(1.351) | .975 | 1.287 |

Manufacturing (or base) industries export supply function:

(2) $V_i \equiv a_i E_i$

This is a set of identities expressing the proportional relationships of exports to value-added in corresponding manufacturing industries; $a_i$'s have been obtained from the St. Louis input-output table.*

| Equation Number | Industry Code | $a_i$ |
|---|---|---|
| (2.1) | SIC 20 | .639 |
| (2.2) | SIC 26 | 1.143 |
| (2.3) | SIC 27 | 1.143 |
| (2.4) | SIC 28 | .553 |
| (2.5) | SIC 29 | .553 |
| (2.6) | SIC 32 | 1.320 |

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*Liu, Ben-chieh, Interindustrial Structure Analysis: An Input-Output Study of the St. Louis Region, 1967, St. Louis Regional Industrial Development Corporation, December, 1968.

(continued)

| Equation Number | Industry Code | $a_i$ |
|---|---|---|
| (2.7) | SIC 33 | .688 |
| (2.8) | SIC 34 | .972 |
| (2.9) | SIC 35 | .781 |
| (2.10) | SIC 36 | .708 |
| (2.11) | SIC 37 | .809 |
| (2.12) | Other Manu. | .949 |

When the model is to be used to simulate the impact of air pollution control costs upon the St. Louis economy, value-added can be derived in terms of both (a) export demands and (b) the ratio of the level of capital stock in the presence of air pollution control costs to the level of capital stock that would have occurred without such control costs:

$$(2') \qquad V^{*}_{it} = \frac{K^{*}_{it}}{K_{it}} \; a_i \, E_{it}$$

Import demand function:

$$(3) \qquad M_{it} = a_i \, V_{it}$$

The levels of manufacturing industry output determine the imports of raw materials and intermediate goods from other regions. Import coefficients ($a_i$) also were obtained from the St. Louis input-output table as was done in the previous formulae.

| Equation Number | Industry Code | $a_i$ |
|---|---|---|
| (3.1) | SIC 20 | .661 |
| (3.2) | SIC 26 | .285 |
| (3.3) | SIC 27 | .285 |
| (3.4) | SIC 28 | .907 |
| (3.5) | SIC 29 | .907 |
| (3.6) | SIC 32 | .329 |
| (3.7) | SIC 33 | .605 |
| (3.8) | SIC 34 | .391 |
| (3.9) | SIC 35 | .342 |
| (3.10) | SIC 36 | .548 |
| (3.11) | SIC 37 | 1.567 |
| (3.12) | Other Manu. | .501 |

Production function with price index adjustment factor:

$$(4) \quad \left(\frac{V_{it}}{P_{NIt}}\right) = A_i e^{r_i t} N_{it}^{\beta i} \left(\frac{K_{it}}{P_{NIt}}\right)^{1-\beta_i}$$

where $\beta_i$ has been calculated as the goometric mean of the annual St. Louis labor share.

| Equation Number | Industrial Code | $A_i$ | $\gamma_i$ | $\beta_i$ | $(1-\beta_i)$ | $R^2$ | D-W Stat. |
|---|---|---|---|---|---|---|---|
| (4.1) | SIC 20 | 3.257<br>(.02073) | .0285<br>(.00293) | .450 | .550 | .711 | 1.629 |
| (4.2) | SIC 26 | 2.766<br>(.0177) | .0225<br>(.00250) | .581 | .419 | .821 | .955 |
| (4.3) | SIC 27 | 4.637<br>(.0282) | .0274<br>(.00399) | .617 | .383 | .914 | .847 |
| (4.4) | SIC 28 | 2.044<br>(.0174) | .0467<br>(.00247) | .319 | .681 | .974 | 2.120 |
| (4.5) | SIC 29 | 1.439<br>(.121) | .0309<br>(.01790) | .316 | .684 | .159 | .777 |
| (4.6) | SIC 32 | 2.605<br>(.0188) | .0251<br>(.00266) | .440 | .560 | .908 | 1.0818 |
| (4.7) | SIC 33 | 3.090<br>(.0658) | .0247<br>(.009305) | .580 | .420 | .841 | 1.735 |
| (4.8) | SIC 34 | 4.473<br>(.0278) | .0284<br>(.00274) | .558 | .412 | .906 | 1.178 |
| (4.9) | SIC 35 | 4.259<br>(.0278) | .0213<br>(.00393) | .577 | .423 | .856 | .829 |
| (4.10) | SIC 36 | 2.234<br>(.0422) | -.0156<br>(.00596) | .586 | .414 | .328 | 1.228 |
| (4.11) | SIC 37 | 4.241<br>(.0469) | .04904<br>(.00663) | .501 | .499 | .957 | 2.338 |
| (4.12) | Other Manu. | 4.269<br>(.0368) | .0186<br>(.00623) | .848 | .152 | .560 | 2.478 |
| All Manufacturing Industry | | 3.554<br>(.0217) | .0360<br>(.00366) | .528 | .472 | .969 | .942 |

Capital share (profit) relation:

(5) $\Pi_{it} = (1 - \gamma_i) V_{it}$

Given the Cobb-Douglas production function, capital share or profit in the broad sense can be derived and the coefficients can be obtained as in the preceding table for the production function. Altogether, there are 12 equations (5. 1) through (5. 12), comparable to those in 4. 1 through 4. 12.

In addition, to consider the effect of air pollution control costs (C) upon industry investment, a modification of the equation(s) is required:

(5') $\Pi_{it}^{*} = \Pi_t - C_i$

Investment function:

The investment functions presented here differ more from industry to industry than do the other equations. This is so, first, because investment functions differ from model to model because there are different theories behind each model (usually involving a lag structure*) and, second, because investment behavior differs from industry to industry and tends to be non-linear. Therefore, the results have been presented individually.

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*For example, see Shirley Almon, "The Distributed Lag Between Capital Appropriations and Expenditures," Econometrica, 1965, pp. 178-196.

(6.1) $I_{20t} = 73.865 + .261\Pi_{20t} - .421\,K_{20t-1}$

$(2.031) \quad (3.27) \quad (2.38)$

$R^2 = .443$
D-W = 2.131

(6.2) $I_{26t} = 1.250 + 3.861\,\delta_t + .0648\Pi_t + .321\,t$

$(2.768) \quad (.811) \quad (.104) \quad (.0763)$

where $\delta = 1$, when $t = 7$; otherwise $\delta = 0$.

$R^2 = .844$
D-W = 2.131

(6.3) $I_{27t} = 11.672 + .0983\Pi_{27t} - .235K_{27t} + 7.927\,\delta$

$(14.910) \quad (.321) \quad (.562) \quad (3.911)$

where $\delta = 1$, when $t = 8, 9, 10$; otherwise $\delta = 0$

$R^2 = .637$
D-W = 2.881

(6.4) $I_{28t} = 10.222 + .114\hat{\Pi} - .0394K_{28t-1}$

$(.0849) \quad (1.328) \quad (.086)$

$R^2 = .440$
D-W = 2.013

(6.5) $I_{29} = 51.01 + .291\Pi_{29t} - .236K_{29t-1}$

$(1.04) \quad (1.78) \quad (1.24)$

$R^2 = .239$
D-W = 1.62

(6.6) $I_{32t} = 174.52 + .0486\,\hat{\Pi} - 1.424\,K_{32t-1}$

$(2.268) \quad (.417) \quad (2.348)$

$R^2 = .353$
D-W = 2.615

(6.7) $I_{33t} = 146.13 + .347\,\Pi_{33t} - .767_{33t-1} + 9.788t$

$(1.22) \quad (2.84) \quad (1.33) \quad (1.755)$

$R^2 = .685$
D-W = 2.425

(6.8) $I_{34t} = -3.950 + .164\Pi_{34t}$

$(2.794) \quad (.0359)$

$R^2 = .622$
D-W = 1.854

(6.9) $I_{35t} = 29.697 + .0829\Pi_{35t} - .369K_{35t} + 5.301\,\delta$

$(26.549) \quad (.132) \quad (.236) \quad (2.165)$

$+ 1.317t$
$(.889)$

where $\delta = 1$, when $t = 4, 5, 6, 7$; otherwise $\delta = 0$

$R^2 = .709$
D-W = 2.260

(6.10) $I_{36t} = -.553 + .0750\,\Pi_t + 4.497\,\delta_t + .169T$

$(1.838) \quad (.0311) \quad (1.0527) \quad (.0790)$

where $\delta = 1$, when $t = 8$; otherwise $\delta = 0$

$R^2 = .709$
D-W = 1.783

(6.11) $I_{37t} = 66.549 + .166\,\Pi_{37t} - .476_{37t-1}$

$(2.05) \quad (3.40) \quad (2.01)$

$R^2 = .589$
D-W = 1.911

(6.12) $I_{other} = -.0919 + .0635\Pi_{other} + .685t$

$(11.111) \quad (.256) \quad (.342)$

$R^2 = .500$
D-W = 2.89

$\sum_i I_i = 618.82 - .424 \sum_i K_{it-1} + .307 \sum_i \Pi_i$

$(457.33) \quad (.275) \quad (.007)$

$R^2 = .906$
D-W = 2.89

Capital stock identity:

(7) $$K_{it} = K_{i,t-1} + I_{it} - d_i K_{it}$$

where $d_i$ is depreciation rate.

| Equation Number | Industry Code | Depreciation rate $d_i$ |
|---|---|---|
| (7.1) | SIC 20 | .0674 |
| (7.2) | SIC 26 | .0534 |
| (7.3) | SIC 27 | .0686 |
| (7.4) | SIC 28 | .0669 |
| (7.5) | SIC 29 | .0614 |
| (7.6) | SIC 32 | .0646 |
| (7.7) | SIC 33 | .0560 |
| (7.8) | SIC 34 | .0700 |
| (7.9) | SIC 35 | .0722 |
| (7.10) | SIC 36 | .0738 |
| (7.11) | SIC 37 | .0784 |
| (7.12) | Other Manu. | .0751 |

Government expenditure equation:

(8) $$G_t = \underset{(15.978)}{27.517} + \underset{(0.0529)}{0.951}\, T_t$$ $R^2 = 0.973$, D-W $d = 2.173$

Regional expenditures:

(9) $$Y_t^* = C_t + \sum_i I_{it} + \sum_i E_{it} - \sum_i M_{it} + G$$

Consumption function:

(10) $$C_t = \underset{(467.215)}{287.524} + \underset{(.0797)}{.592}\,Y_t^*$$ $R^2 = .990$ D-W $d = .882$

(10) has been estimated by two-stage least squared method.

Relation between regional expenditure Y* and regional income Y:

(11) $$Y_t = \underset{(310.85)}{-3667.206} + \underset{(.053)}{1.565}\,Y_t^*$$ $R^2 = .989$ D-W $d = 2.06$

Employment by industries other than manufacturing industries:

(12) $$\overline{N}_t = \underset{(37.88)}{384.798} + \underset{(.0146)}{.0821}\,(Y_t - \sum_i V_{it})$$ $R^2 = .793$ D-W $d = 2.19$

Total employment:

(13) $$N_t \equiv \sum_i N_{it} + \overline{N}_t$$

Labor force function:

(14) $$L_t = \underset{(63.74)}{68.01} + \underset{(.0539)}{.9384}\,N_t + \underset{(3.427)}{5.366}\,u_{Nt}$$ $R^2 = .995$ D-W $d = 1.18$

Regional unemployment:

(15) $$U_t \equiv L_t - N_t$$

Regional unemployment rate:

(16) $$u_t \equiv \frac{U_t}{L_t} \times 100$$

Electric power demand functions for manufacturing industries:

(17) $$Q_{it} = a_i + b_i V_{it} + c_i t$$

| Equation Number | Industry Code | $a_i$ | $b_i$ | $c_i$ | $R^2$ | D-W d |
|---|---|---|---|---|---|---|
| (17.1) | SIC 20 | -39.302<br>(71.82) | .5970<br>(.2054) | 8.171<br>(1.974) | .937 | 1.875 |
| (17.2) | SIC 26 | $-6.706 + 44.12d + .2978V_{26t}$<br>(12.46) (1.95) (.204)<br>$+ 5.758t$<br>(.449)<br>where $d = 1$ if $t < 6$; $d = 0$ if $t \geq 6$ | | | .984 | 2.41 |
| (17.3) | SIC 27 | -11.361<br>(1.586) | .4063<br>(.7791) | | .857 | 1.259 |
| (17.4) | SIC 28 | 79.910<br>(.919) | .3252<br>(.0495) | 38.992<br>(2.781) | .914 | .906 |
| (17.5) | SIC 29 | 120.806<br>(10.103) | .2672<br>(.1935) | 21.031<br>(15.450) | .975 | 1.944 |
| (17.6) | SIC 32 | 160.527<br>(.837) | 1.0533<br>(.0558) | 7.424<br>(1.036) | .450 | .806 |
| (17.7) | SIC 33 | -65.049<br>(.873) | 1.3238<br>(.3553) | 2.505<br>(.296) | .787 | 1.823 |
| (17.8) | SIC 34 | -58.124<br>(1.814) | .8176<br>(.4963) | | .703 | .521 |
| (17.9) | SIC 35 | 24.652<br>(2.955) | .1070<br>(.2430) | | .329 | 1.475 |
| (17.10) | SIC 36 | 19.996<br>(.692) | .7681<br>(.4305) | -1.450<br>(1.750) | .623 | 2.296 |
| (17.11) | SIC 37 | 24.206<br>(1.10) | .4236<br>(.3925) | 8.095<br>(1.180) | .972 | 1.925 |
| (17.12) | Other Manu. | -33.100<br>(287.8) | .2178<br>(.0966) | 1.665<br>(8.516) | .555 | 1.443 |
| All Manufacturing Industry | | -633.620<br>(193.74) | 1.1356<br>(.861) | 13.410<br>(13.693) | .993 | 1.976 |

Electric power demand function for residential users:

(18) $$Q_{ct} = -1548.94 + .9485\, C_t \qquad R^2 = .972$$

$$\quad (201.75) \quad (.538) \qquad \text{D-W } d = .566$$

Electric power demand function of the industries other than manufacturing industries:

(19) $$\overline{Q}_t = 479.98 + .4552\,(Y_t - \sum_i V_{it}) \qquad R^2 = .895$$

$$\quad (129.36) \quad (.0516) \qquad \text{D-W } d = .1.81$$

Wage function: Collective bargaining power should also be included in the model for wage determination:

(20) $$w_{it} = w_{io}\, a_i^t$$

where $w_{io}$ is wage (per man-year) at 1954 by industry i.

| Equation Number | Industry Code | $w_{io}$ (\$1000) | $a_i$ | $R^2$ |
|---|---|---|---|---|
| (20.1) | SIC 20 | 4.505 | 1.0413 | .996 |
| (20.2) | SIC 26 | 3.918 | 1.0407 | .991 |
| (20.3) | SIC 27 | 4.744 | 1.0343 | .990 |
| (20.4) | SIC 28 | 4.641 | 1.0422 | .998 |
| (20.5) | SIC 29 | 5.181 | 1.0409 | .993 |
| (20.6) | SIC 32 | 4.062 | 1.0461 | .986 |
| (20.7) | SIC 33 | 4.509 | 1.0474 | .988 |
| (20.8) | SIC 34 | 4.211 | 1.0430 | .995 |
| (20.9) | SIC 35 | 4.410 | 1.0419 | .998 |

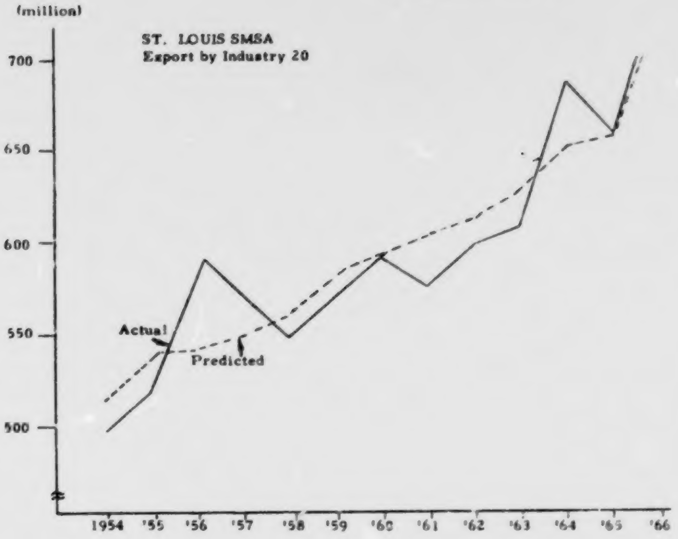
(continued)

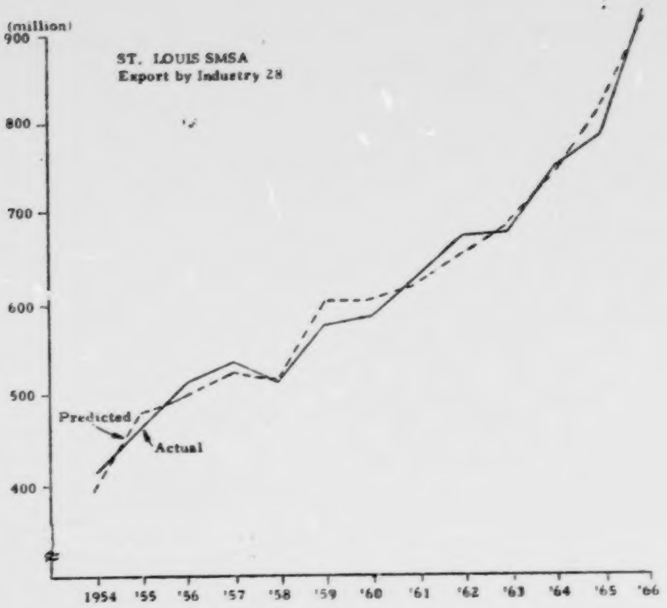
| Equation Number | Industry Code | $w_{io}$ (\$1000) | $a_i$ | $R^2$ |
|---|---|---|---|---|
| (20.10) | SIC 36 | 4.305 | 1.0323 | .994 |
| (20.11) | SIC 37 | 4.662 | 1.0519 | .995 |
| (20.12) | Other Manu. | 3.283 | 1.0562 | .986 |

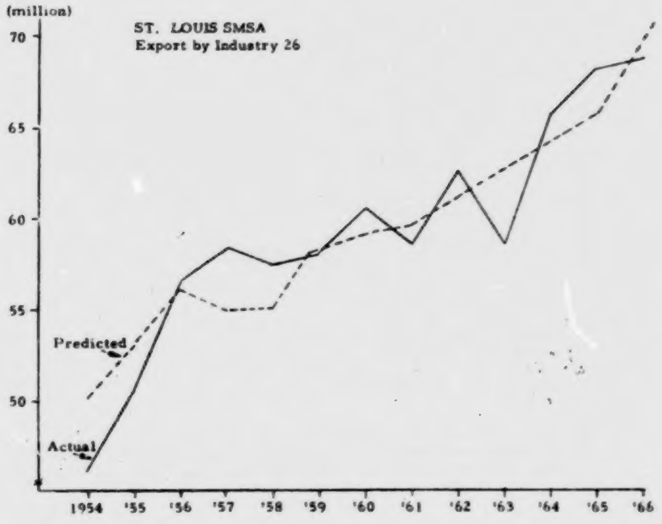
FIGURE A. 1

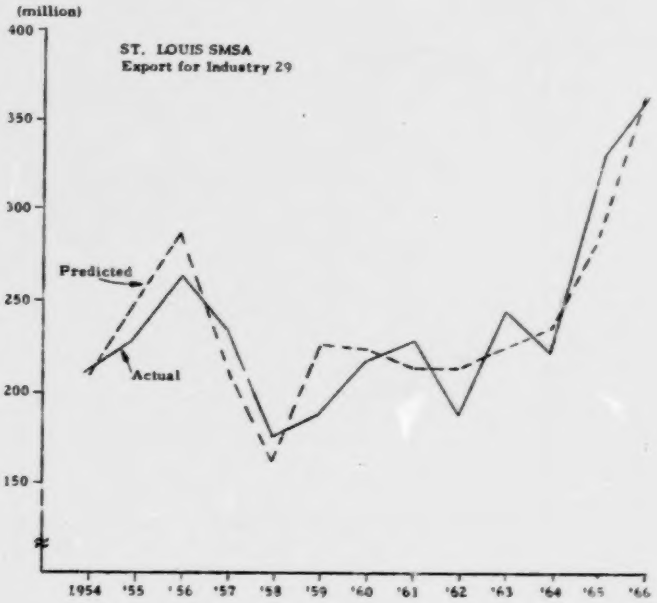
ACTUAL VERSUS PREDICTED REGIONAL
EXPORTS BY MAJOR TWO-DIGIT MANUFACTURING
INDUSTRIES IN ST. LOUIS SMSA

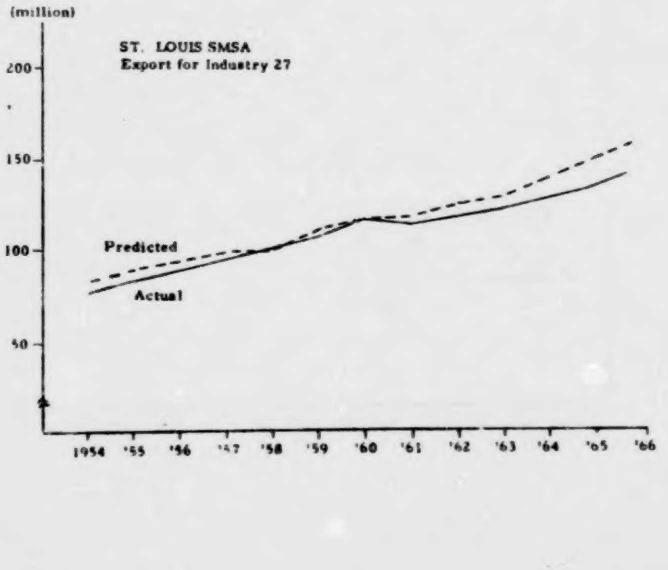
Figure A. 1

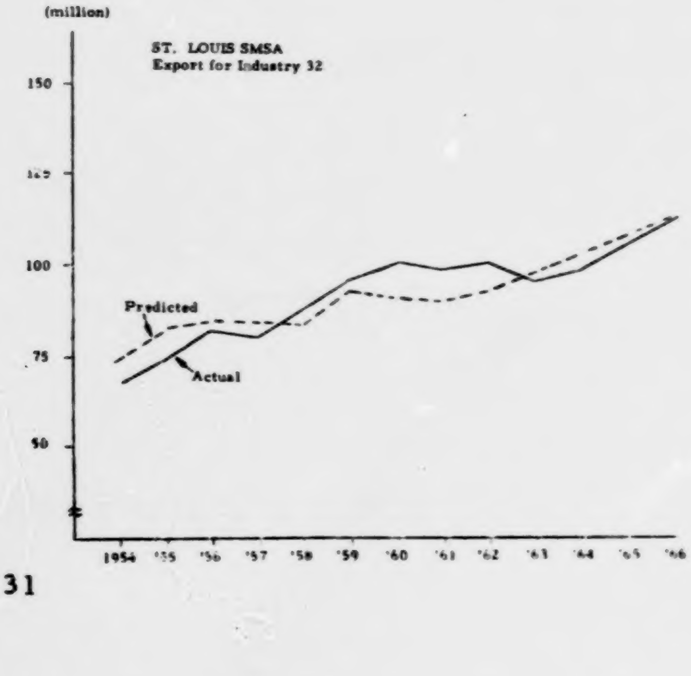

(million)
ST. LOUIS SMSA
Export by Industry 20
700
650
600
550
500
Actual
Predicted
1954
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66


(million)
900
ST. LOUIS SMSA
Export by Industry 28
800
700
600
500
400
Predicted
Actual
1954
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66

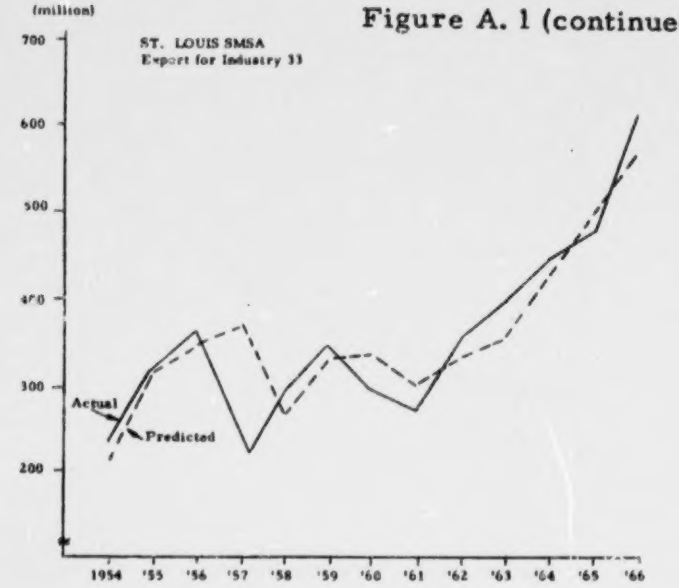

(million)
ST. LOUIS SMSA
Export by Industry 26
70
65
60
55
50
Predicted
Actual
1954
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66

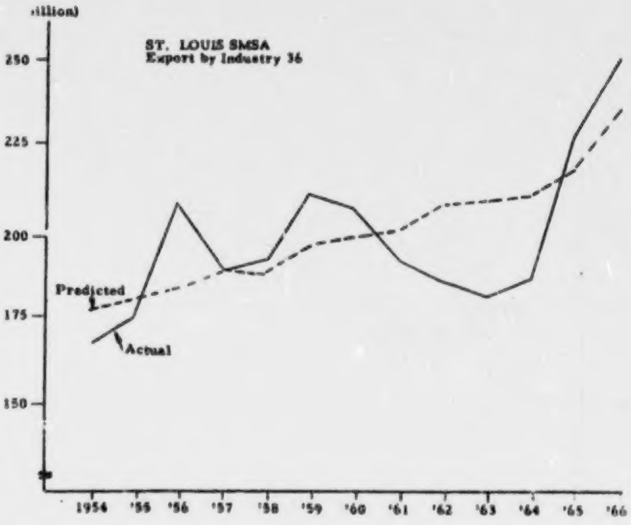

(million)
400
ST. LOUIS SMSA
Export for Industry 29
350
300
250
200
150
Predicted
Actual
1954
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66

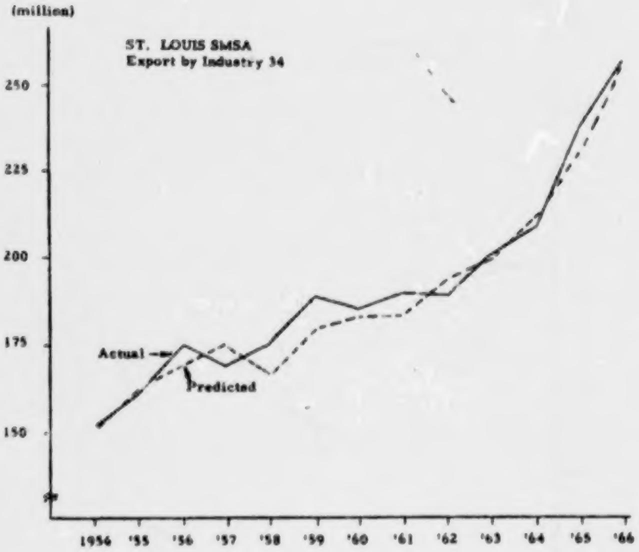

(million)
ST. LOUIS SMSA
Export for Industry 27
200
150
100
50
Predicted
Actual
1954
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66

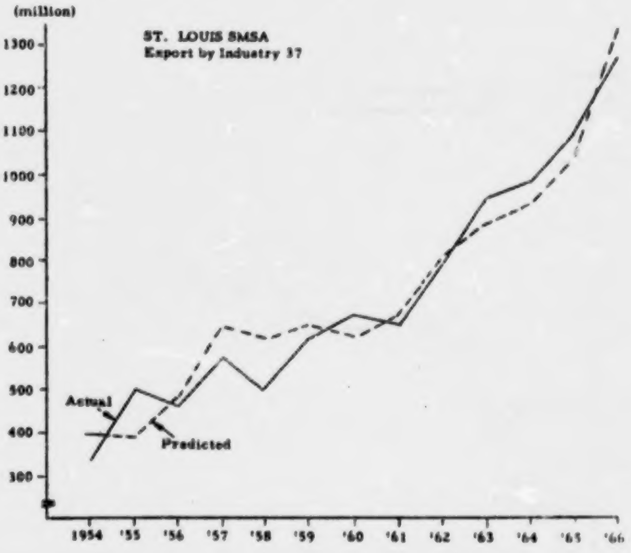

(million)
ST. LOUIS SMSA
Export for Industry 32
150
125
100
75
50
Predicted
Actual
1954
'55
'56
'57
'58
'59
'60
'61
'62
'63
'64
'65
'66

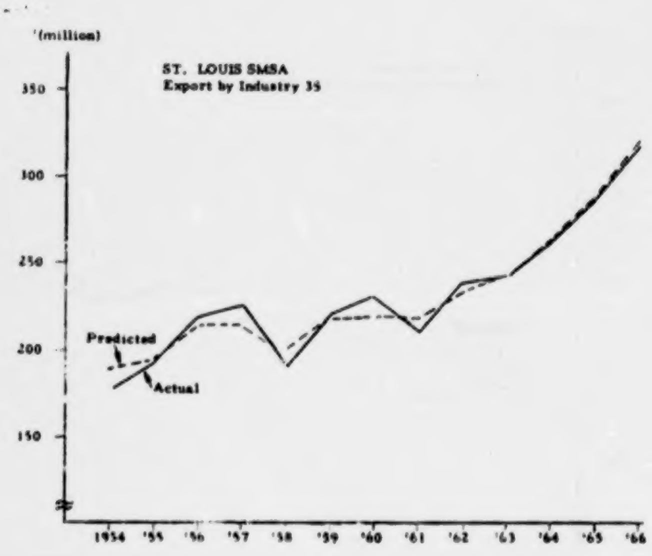
## Figure A. 1 (continued)

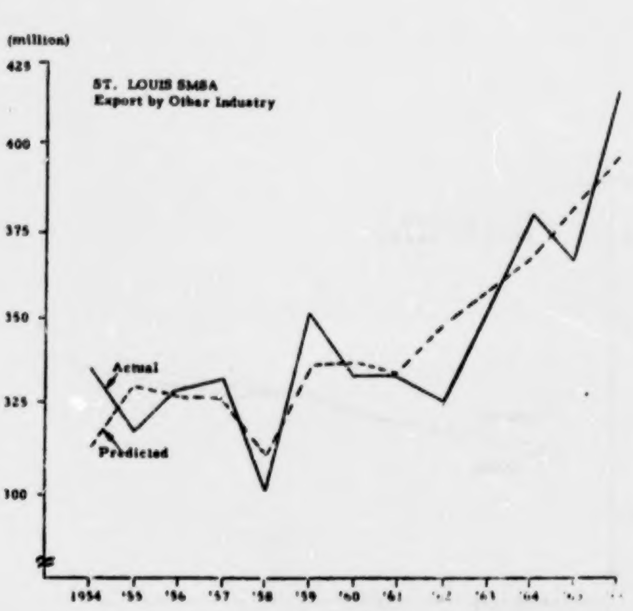












# APPENDIX B

## 31 AQCR MODEL
## (PHASE II)

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## Appendix B: 31 AQCR Model

### Introduction

In the first year of model development, CONSAD developed a Regional Econometric Model of the St. Louis metropolitan region, based on the time series data. In the second year program plan, the aim has been to focus on the development of a cross-sectional regional econometric model which includes 31 AQCRs across the country. In this model, the roles of Keynsian theory and regional export base theory will remain as the basic framework as before. However, the entire equation system has been reformulated in order to integrate the cross-sectional structure into the model.

At the regional level, cross-sectional models are not uncommon for the single equation model (as are some partial equilibrium-type models), partially due to the fact that time series data are usually unavailable in continuous time series form. However, an economy-wide cross-section model, at this stage, is more a conceptual constrict than a well-developed operational model.* This is partially due to the fact that growth models at the national level always deal with time series data, for a country, unless international comparisons of the growth patterns are the focus.

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*Some Keynsian type cross-sectional models have been suggested in Carl F. Christ, Econometric Models and Methods, New York, 1966, and a cross-sectional income model has been estimated in J. M. Mattila and W. R. Thompson, "Toward an Econometric Model of Urban Economic Development," (Appendix), Issues in Urban Economics, edited by H. S. Perloff and L. Wingo, Jr., Resources for the Future, 1968.

### A Cross-Section Regional Econometric Model

There is a fundamental difference between the economy of metropolitan regions and the national economy. The former is based on an open economy where growth and development is closely related to its capability to carry on external trade with other regions. The latter is rather more self-contained by its nature. In spite of the Keynsian macro-economic theory, the concept of "export-base" or economic base theory, has been the core of the analytical frameworks of urban economies since its first appearance in 1928.* However, the measurement of the economic base multipliers originally based on calculation of the ratio between export-oriented (or basic) employment and local-oriented (or service) employment has been changed by using the concept of value-added instead of employment.**

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*Haig, Robert M., Major Economic Factors in Metropolitan Growth and Arrangement, Vol. I, Regional Survey of New York and Environs, New York, 1928. See also Thompson, Wilbur R., A Preface to Urban Economics, Resources for the Future, 1965.

**As an early example, see Leven, Charles L., "Measuring the Economic Base," Papers and Proceedings, Vol. 2, The Regional Science Association, 1956.

This later development now takes into account different production structures among local industries, so that factor intensity of capital and labor may contribute different weight to the multiplier. Since manufacturing industries are more capital-intensive, the role of manufacturing industries in regional growth becomes decisive in that they usually dominate the value of exports greater than 80 percent of the total value-added.* It is therefore quite safe to treat manufacturing industry as an export-oriented industry in the regional growth model that in some of the recent successful regional econometric models explicitly or implicitly embodied a causal relationship of manufacturing industry leads the overall regional growth.**

The change in the measurement from employment to value-added in economic base theory not only has improved the applicability of the regional multiplier in recent regional growth analysis, but it also seems to be consistent with the familiar Keynsian-type trade multiplier in the open economic system. However, economic base theory is only a partial phenomenon in that it explains the demand side of the urban growth without proper inclusion of the supply side.* The relations between labor and capital markets, export-oriented industry and other local service industry, are also important. Details are given in the formulation of the entire model.

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*In a case study of five midwest metropolitan areas, Charles C. Leven reported that manufacturing industry dominates 80 to 96 percent of export measured by value-added, while it only counts 45 to 71 percent if it were measured by employment.

**A typical and successful model of this nature is Frederick W. Bell, op. cit.

Since the main interest in this model is focused on air pollution control, the sectoral structure must be based on criteria that reflect the major air pollution industries being considered in the present study. In total, 13 manufacturing industries have been chosen as shown in Table B.1.**

The variables of the model developed in this section can be specified and defined as follows:

$Y_i$ = regional income of ith SMSA,

$C_i$ = regional consumption expenditure of ith SMSA,

$I_{ij}$ = investment expenditure by industry j of ith SMSA,

$\Pi_{ij}$ = capital share or gross profit by industry j of ith SMSA,

$K_{ij}$ = capital stock by industry j of ith SMSA,

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*Thompson, W. R., op. cit., pp. 27-60.

**See CONSAD Research Corporation, Progress Report on Sectoral Structure and Data Collection, prepared for TRW Systems, Inc., September 20, 1969. This classification has been based on the information available in R. L. Duprey, Compilation of Air Pollution Emission Factors, Washington, D.C., Department of Health, Education and Welfare, Public Health Service, 1968.

## TABLE B. 1

## CLASSES OF MANUFACTURING INDUSTRIES

| Industry Title | Related SIC Codes |
|---|---|
| Canning and grain mill products | 203, 204 |
| Fabrics, yarn and thread mills | 221, 222, 223, 224, 226, 228 |
| Paper and allied products | 26 |
| Chemicals and selected chemical products | 281, 286, 287, 289 |
| Petroleum refining and related industries | 29 |
| Rubber and plastics products | 30 |
| Glass and glass products | 321-323 |
| Stone and clay products | 324-329 |
| Primary iron and steel, copper and aluminum manufacturing | 331, 332, 3391, 3399, 3331, 3351, 3362, 2819, 3334, 3352, 3361 |
| Other non-ferrous metals manufacturing | 3332, 3333, 3339, 3341, 3356, 3357, 3369, 3392 |
| Motor vehicles and equipment | 371 |
| Aircraft and other transportation equipment | 372-379 |
| Other manufacturing industries | 20-39, except included in above classification |

$X_{ij}$ = value-added by industry j of $i^{th}$ SMSA,

$N_{ij}$ = employment by industry j of $i^{th}$ SMSA,

$W_{ij}$ = average wage by industry j of $i^{th}$ SMSA,

$u_i$ = unemployment rate of $i^{th}$ SMSA,

$U_i$ = unemployment of $i^{th}$ SMSA,

$\overline{N}_i$ = employment by industries other than manufacturing industries of $i^{th}$ SMSA,

$N_i^T$ = $(\sum_j N_{ij} + \overline{N}_i)$ total regional employment of $i^{th}$ SMSA,

$L_i$ = regional labor force of $i^{th}$ SMSA,

$P_i$ = population of $i^{th}$ SMSA,

$Q_{ij}$ = electric power demand by industry of $i^{th}$ SMSA,

$M_i$ = migration of $i^{th}$ SMSA,

$G_i$ = government expenditure of $i^{th}$ SMSA,

$T_i$ = government revenue of $i^{th}$ SMSA.

Integration of the Keynesian system and economic base theory can be best explained by the income determination block of this model:

(1) $$Y_i = f(C_i, \sum_j X_{ij}, G_i)$$

(2) $$C_i = f(Y_i, C_i\ (t-1))$$

(3) $$G_i = f(T_i)$$

This model is a cross-sectional regional growth model. Thus, the national influence upon a local economy can be measured by the regional market share of the output in each manufacturing industry.

Because manufacturing is also regarded as export-oriented, the value-added, $\sum_j X_{ij}$, also reflects the role of economic base theory of local demand, namely, local consumption and government expenditures. In this model, therefore, government expenditure is a simple function of government revenue.

The sectoral structure of the export-oriented industries has been based on 13 sectors.

(4) $X_{ij}(t) = f(Y_i(t), Y_i(t-1), X_{ij}(t-1))$ $j=1,\ldots,13$

(5) $I_{ij}(t) = f(\Pi_{ij}(t), K_{ij}(t-1))$ $j=1,\ldots,13$

(6) $K_{ij}(t) = K_{ij}(t-1) + I_{ij}(t) - d_j K_{ij}(t)$ $j=1,\ldots,13$

(7) $X_{ij}(t) = A_{ij} N_{ij}^{a}(t) K_{ij}^{1-a}(t)$ $j=1,\ldots,13$

(8) $W_{ij}(t) = f(u_i, M_i, W_{ij}(t-1))$ $j=1,\ldots,13$

(9) $Q_{ij}(t) = f(X_{ij}(t))$ $j=1,\ldots,13$

Equation (4) is the demand function for the products in terms of the value-added by industry j in region i, where $Y_i(t)$ and $Y_i(t-1)$ includes both local and external market demand of present and previous years, and $X_{ij}(t-1)$ measures market share from the previous period. Equation (5) is a typical investment function and equations (6) and (7) are familiar production structures developed in the St. Louis Model. Since output level (value-added) and capital stock have been determined by the three previous equations ((4), (5), and (6)), equation (7) becomes an implicit demand function for labor requirements by industry j ($N_{ij}$).

Wages (equation 8) are a function of the local unemployment rate ($U_i$), migration ($M_i$) and lagged wages ($W_{ij}$ (t-1)). This relationship not only includes labor productivity but it also shows, in part, the union bargaining power based on the last period wage level. Finally, equation (9), electric power demand by industry, is expressed in terms of a single function, current industrial output levels.

The equations for total industrial employment, other than for manufacturing industries, and therefore a functional description for the labor market in the regional economic model, is as follows:

$$(10) \qquad \overline{N}_i = f(Y_i - \Sigma X_{ij})$$

$$N_i^T = \sum_j N_{ij} + \overline{N}_i$$

$$(12) \qquad L_i = f(u_i, P_i, \sum_j W_{ij} N_{ij} / \sum_j N_{ij})$$

$$(13) \qquad U_i = L_i - N_i^T$$

$$(14) \qquad u_i = \frac{L_i - N_i^T}{L_i} \times 100$$

Equation (10) is a labor demand function for the industries other than manufacturing industry. Equation (11) is derived from equations (7) and (10). Equation (12) represents the supply side of the labor market. The labor force ($L_i$) is expressed as a function of regional unemployment ($u_i$), the weighted average wage rate ($\sum_j W_{ij} N_{ij} / \sum_j N_{ij}$) and size of the population ($P_i$). Unemployment in equation (13) is the result of the difference between the size of the labor force and total regional employment. The amount of unemployment is expressed as a rate of unemployment in equation (14).

AQCRs Included in the Model

The main interest of the Phase II Regional Econometric Model was on the ability of the model to be applied to the major cities across the country. In total, the 31 largest SMSAs have been chosen for the present model. The size of the city, in general, is reported to be consistent with the degree of the severity of the air pollution problem.* In the following Table B.2, both rank in size of population and in severity of air pollution have been included for the cities under study.

Model Estimation

The model developed in Section 2.2.2 has been estimated on the data from 31 largest SMSAs:

Regional income equation:

$$(1)\qquad Y_i = \underset{(194.4)}{64.78} + \underset{(0.137)}{0.702}\, C_i + \underset{(0.100)}{0.481} \sum_{j=1}^{13} X_{ij} + \underset{(0.591)}{3.02}\, G_i \qquad R^2=0.994$$

Regional consumption function:

$$(2)\qquad C_i = \underset{(40.9)}{15.11} + \underset{(0.030)}{0.012}\, Y_i + \underset{(0.048)}{1.061}\, C_{it-1} \qquad R^2=0.999$$

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*Middleton, John T., "Air Pollution: How 65 Metropolitan Areas Rank in Severity," Nation's Cities, Vol. 5, No. 8, August, 1967, pp. 8-11/

## TABLE B.2

| Code | SMSA | Rank of City* | Rank of Severity** |
|---|---|---|---|
| 1 | New York, New York | 1 | 1 |
| 2 | Chicago, Illinois | 2 | 2 |
| 3 | Los Angeles/Long Beach, California | 3 | 4 |
| 4 | Philadelphia, Pa. - New Jersey | 4 | 3 |
| 5 | Detroit, Michigan | 5 | 9 |
| 6 | San Francisco/Oakland, California | 6 | 35 |
| 7 | Pittsburgh, Pennsylvania | 8 | 6 |
| 8 | St. Louis, Missouri - Illinois | 9 | 10 |
| 9 | Washington, D. C. - Maryland - Va. | 10 | 18 |
| 10 | Cleveland, Ohio | 11 | 5 |
| 11 | Baltimore, Maryland | 12 | 13 |
| 12 | Newark, New Jersey | 13 | 8 |
| 13 | Minneapolis/St. Paul, Minnesota | 14 | 32 |
| 14 | Houston, Texas | 15 | 43 |
| 15 | Buffalo, New York | 16 | 30 |
| 16 | Milwaukee, Wisconsin | 17 | 20 |
| 17 | Cincinnati, Ohio - Indiana - Kentucky | 18 | 19 |
| 18 | Paterson/Clifton/Passaic, New Jersey | 19 | 21 |
| 19 | Dallas, Texas | 20 | 57 |
| 20 | Seattle/Everett, Washington | 21 | 36 |
| 21 | Kansas City, Kansas | 22 | 25 |
| 22 | San Diego, California | 23 | 61 |
| 23 | Atlanta, Georgia | 24 | 51 |
| 24 | Indianapolis, Indiana | 25 | 14 |
| 25 | Miami, Florida | 26 | 63 |
| 26 | Denver, Colorado | 27 | 27 |
| 27 | New Orleans, Louisiana | 28 | 59 |
| 28 | Portland, Oregon - Washington | 29 | 49 |
| 29 | Columbus, Ohio | 33 | 46 |
| 30 | Rochester, New York | 34 | 53 |
| 31 | Dayton, Ohio | 35 | 26 |

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*Rank of city is based on the size of the population reported in Current Population Reports: Technical Studies, Series P-23, No. 23, October, 1967. Boston SMSA ranked 7th, Providence-Pawtucket-Warwick SMSA ranked 30th, San Bernadino-Riverside-Ontario SMSA ranked 31st and Tampa-St. Petersburg SMSA have been excluded from present study because of changes in definition of SMSA or lack in certain type of data.

**See John T. Middleton, ibid.

Demand function of export-oriented industry:

(3) $$X_{ijt} = a_j + b_j Y_{it} + c_j Y_{it-1} + d_j X_{ijt-1} \qquad j=1,2,\ldots,13$$

The results of estimation are:

| Equation Number | Industry Code | $a_j$ | $b_j$ | $c_j$ | $d_j$ | $R_2$ |
|---|---|---|---|---|---|---|
| (3.1) | 1 | -441.9<br>(532.0) | .103<br>(.65) | -.155<br>(.698) | 1.135<br>(.009) | .998 |
| (3.2) | 2 | 224.3<br>(242.3) | .116<br>(.218) | -.160<br>(.232) | 1.085<br>(.006) | .999 |
| (3.3) | 3 | -529.3<br>(1138.7) | .672<br>(1.38) | -.942<br>(1.47) | 1.122<br>(.013) | .998 |
| (3.4) | 4 | -97.52<br>(927.9) | .252<br>(1.11) | -.220<br>(1.18) | 1.090<br>(.005) | .999 |
| (3.5) | 5 | -449.9<br>(927.8) | .313<br>(1.08) | -.234<br>(1.15) | 1.097<br>(.006) | .999 |
| (3.6) | 6 | -695.9<br>(946.7) | .635<br>(1.20) | -.864<br>(1.29) | 1.135<br>(.012) | .998 |
| (3.7) | 7 | -57.36<br>(117.7) | 1.899<br>(.717) | -2.028<br>(.767) | 1.061<br>(.003) | .999 |
| (3.8) | 8 | -1745.2<br>(1089.7) | .738<br>(1.248) | -.890<br>(1.34) | 1.131<br>(.013) | .997 |
| (3.9) | 9 | -6063.1<br>(5835.1) | 3.783<br>(6.07) | -3.580<br>(7.04) | 1.095<br>(.008) | .998 |
| (3.10) | 10 | -412.4<br>(710.5) | 9.380<br>(2.59) | 10.127<br>(2.77) | 1.121<br>(.011) | .999 |
| (3.11) | 11 | 4680.7<br>(6835.9) | 1.309<br>(.814) |  | 1.047<br>(.006) | .999 |

(continued)

| Equation Number | Industry Code | $A_j$ | $b_j$ | $c_j$ | $d_j$ | $R_2$ |
|---|---|---|---|---|---|---|
| (3.12) | 12 | -3165.2<br>(3635.3) | 60.785<br>(23.32) | -66.56<br>(24.89) | 1.159<br>(.008) | .999 |
| (3.13) | 13 | 23296.6<br>(29916.3) | 7.337<br>(41.2) | -26.331<br>(42.7) | 1.154<br>(.030) | .997 |

Production functions:

(4) $X_{ij} = A_j N_{ij}^{a_j} K_{ij}^{1-a_j}$ $j=1,\ldots 13$

| **Equation Number** | **Industry Code** | $A_j$ | $a_j$ | $1-a_j$ | $R_2$ |
|---|---|---|---|---|---|
| **(4.1)** | **1** | **4.505<br>(1.002)** | **.5217** | **.4783** | **.974** |
| **(4.2)** | **2** | **2.6375<br>(.659)** | **.5208** | **.4792** | **.993** |
| **(4.3)** | **3** | **3.1312<br>(.418)** | **.5315** | **.4685** | **.993** |
| **(4.4)** | **4** | **4.708<br>(.919)** | **.5269** | **.4731** | **.973** |
| **(4.5)** | **5** | **2.924<br>(.811)** | **.5293** | **.4707** | **.983** |
| **(4.6)** | **6** | **4.000<br>(.366)** | **.5215** | **.4785** | **.997** |
| **(4.7)** | **7** | **3.548<br>(.531)** | **.5085** | **.4915** | **.986** |
| **(4.8)** | **8** | **3.579<br>(.525)** | **.5269** | **.4731** | **.995** |
| **(4.9)** | **9** | **3.296<br>(.423)** | **.5301** | **.4699** | **.998** |

(continued)

| Equation Number | Industry Code | $A_j$ | $\alpha_j$ | $1-\alpha_j$ | $R_2$ |
|---|---|---|---|---|---|
| (4.10) | 10 | 3.559<br>(.525) | .5292 | .4708 | .997 |
| (4.11) | 11 | 4.517<br>(1.101) | .5252 | .4748 | .998 |
| (4.12) | 12 | 6.204<br>(.358) | .5231 | .4769 | .996 |
| (4.13) | 13 | 4.656<br>(.358) | .5269 | .4731 | .998 |

Capital share (or gross profit) relation:

Given the Cobb-Douglas production function, capital share or gross profit can be derived as follows:

(5) $$\Pi_{ij} = (1 - \alpha_j)\, X_{ij} \qquad j=1, \ldots, 13$$

Capital shore coefficients, $\alpha_j$, can be obtained as in the preceding table for the production function. Therefore, there are 13 equations (5.1) through (5.13).

Investment function:

(6) $$I_{ijt} = a_j + b_j\, \Pi_{ijt} + c_j\, K_{ijt-1} \qquad j=1, \ldots, 13$$

| Equation Number | Industry Code | $a_j$ | $b_j$ | $c_j$ | $R_2$ |
|---|---|---|---|---|---|
| (6. 1) | 1 | -420. 6 | . 168 | . 0788 | . 963 |
| | | (326. 1) | (. 067) | (. 0516) | |
| (6. 2) | 2 | -40. 24 | . 4707 | -. 0809 | . 986 |
| | | (183. 7) | (. 116) | (. 0526) | |
| (6. 3) | 3 | -903. 6 | . 6033 | -0. 0852 | . 963 |
| | | (949. 3) | (. 099) | (. 0411) | |
| (6. 4) | 4 | -123. 1 | -. 067 | . 2032 | . 971 |
| | | (824. 1) | (. 047) | (. 0304) | |
| (6. 5) | 5 | -624. 5 | -. 4419 | . 2792 | . 974 |
| | | (1668. 6) | (. 133) | (. 034) | |
| (6. 6) | 6 | -782. 2 | . 4573 | -. 1403 | . 967 |
| | | (504. 4) | (. 0942) | (. 0682) | |
| (6. 7) | 7 | 87. 10 | . 0686 | . 1004 | . 989 |
| | | (108. 2) | (. 147) | (. 079) | |
| (6. 8) | 8 | -2046. 9 | . 0686 | . 1004 | . 989 |
| | | (1078. 2) | (. 126) | (. 0589) | |
| (6. 9) | 9 | -2923. 3 | . 6747 | -. 0979 | . 992 |
| | | (2378) | (. 0595) | (. 023) | |
| (6. 10) | 10 | -62. 79 | . 6177 | -. 1568 | . 982 |
| | | (414. 1) | (. 118) | (. 062) | |
| (6. 11) | 11 | 5832. 6 | . 2157 | . 0034 | . 986 |
| | | (2637. 3) | (. 0398) | (. 025) | |
| (6. 12) | 12 | 1459. 8 | . 2174 | -. 1571 | . 979 |
| | | (997. 9) | (. 044) | (. 078) | |
| (6. 13) | 13 | (11708. 3) | . 3586 | -. 1348 | . 964 |
| | | (11516) | (. 048) | (. 0412) | |

Capital stock identity:

(7) $$K_{ijt} = K_{ijt-1} + I_{ijt} = d_j K_{ijt} \qquad j=1,\ldots,13$$

where $d_j$ is depreciation rate in industry j.

| Equation Number | Industry Code | Depreciation Rate $d_j$ |
|---|---|---|
| (7.1) | 1 | .0675 |
| (7.2) | 2 | .0480 |
| (7.3) | 3 | .0534 |
| (7.4) | 4 | .0643 |
| (7.5) | 5 | .0614 |
| (7.6) | 6 | .0618 |
| (7.7) | 7 | .0625 |
| (7.8) | 8 | .0624 |
| (7.9) | 9 | .0564 |
| (7.10) | 10 | .0529 |
| (7.11) | 11 | .0806 |
| (7.12) | 12 | .0736 |
| (7.13) | 13 | .0714 |

Wage functions:

(8) $$W_{ijt} = a_j + b_j W_{ijt-1} + c_j u_i + d_j M_i \qquad j=1,\ldots,13$$

| Equation Number | Industry Code | $a_j$ | $b_j$ | $c_j$ | $d_j$ | $R_2$ |
|---|---|---|---|---|---|---|
| (8.1) | 1 | .3388<br>(.402) | .985<br>(.031) | -.0516<br>(.0969) | -.0183<br>(.022) | .981 |
| (8.2) | 2 | -.658<br>(.458) | 1.009<br>(.063) | .2109<br>(.106) | -.0069<br>(.0195) | .949 |
| (8.3) | 3 | -2.103<br>(.482) | 1.2906<br>(.066) | .1455<br>(.112) | .0384<br>(.0263) | .944 |
| (8.4) | 4 | .6105<br>(.432) | .9961<br>(.032) | -.1556<br>(.146) | -.0135<br>(.0298) | .979 |
| (8.5) | 5 | .0244<br>(.454) | .9782<br>(.023) | .0098<br>(.135) | .0473<br>(.028) | .987 |
| (8.6) | 6 | .4938<br>(.399) | .9593<br>(.059) | -.0909<br>(.076) | .0025<br>(.018) | .911 |
| (8.7) | 7 | .0817<br>(.171) | 1.0179<br>(.018) | -.0214<br>(.044) | .0062<br>(.010) | .996 |
| (8.8) | 8 | .1974<br>(.571) | 1.048<br>(.055) | -.1399<br>(.127) | -.0275<br>(.032) | .934 |
| (8.9) | 9 | .2051<br>(.522) | 1.0629<br>(.085) | -.1701<br>(.175) | -.0233<br>(.039) | .917 |
| (8.10) | 10 | .2925<br>(.120) | .8941<br>(.018) | .0419<br>(.025) | .0206<br>(.006) | .998 |
| (8.11) | 11 | -.2676<br>(1.34) | .9721<br>(.064) | .2279<br>(.490) | .0057<br>(.064) | .938 |
| (8.12) | 12 | .2202<br>(.416) | .9936<br>(.029) | .0906<br>(.157) | -.0050<br>(.0195) | .984 |
| (8.13) | 13 | .8552<br>(.90) | 1.0008<br>(.078) | -.2850<br>(.278) | -.0443<br>(.035) | .847 |

Employment by industries other than manufacturing industries:

(9) $$\overline{N}_i = 121.73 + 0.1262\,(Y_i - \sum_{j=1}^{13} X_{ij}) \qquad R^2 = 0.968$$
$$(31.96)\ (0.004)$$

Total employment:

(10) $$\overline{N}_i^T = \overline{N}_i + \sum_{j=1}^{13} N_{ij}$$

Labor force supply function:

(11) $$L_i = \underset{(149.9)}{312.735} + \underset{(0.005)}{0.4662}\,P_i - \underset{(18.62)}{39.749}\,(\sum_{j=1}^{13} W_{ij} N_{ij} / \sum_{j=1}^{13} N_{ij})$$
$$- \underset{(17.1)}{31.319}\,u_i \qquad R^2 = 0.995$$

Regional employment

(12) $$U_i = L_i - N_i^T$$

Regional unemployment rate:

(13) $$u_i = \frac{U_i}{L_i} \times 100$$

Electric power demand function by industry:

(14) $$Q_{ijt} = a_j + b_j V_{ijt}$$

| Equation Number | Industry Code | $a_j$ | $b_j$ | $R^2$ |
|---|---|---|---|---|
| (14.1) | 1 | 4.6152<br>(2.81028) | .79804<br>(.042681) | .933 |
| (14.2) | 2 | 29.0536<br>(11.39258) | .205259<br>(.27310) | .799 |
| (14.3) | 3 | 2.49808<br>(.00002362) | -.0049799<br>(.0031956) | .999 |

| Equation Number | Industry Code | $a_j$ | $b_j$ | $R^2$ |
|---|---|---|---|---|
| (14.4) | 4 | -22.75882<br>(32.82634) | 11.98117<br>(.20547) | .991 |
| (14.5) | 5 | -.0051536<br>(.0052080) | 3.76464<br>(.00003890) | .999 |
| (14.6) | 6 | -0.0054016<br>(.0017908) | 1.50925<br>(.00001555) | .999 |
| (14.7) | 7 | -5.84172<br>(4.16915) | 1.83096<br>(.14389) | .915 |
| (14.8) | 8 | 0.028437<br>(3.85147) | 2.38909<br>(.033961) | .994 |
| (14.9) | 9 | 2.01174<br>(253.2238) | 5.15529<br>(.39807) | .879 |
| (14.10) | 10 | -5.53004<br>(2.19407) | 1.76572<br>(.05378) | .994 |
| (14.11) | 11 | -11.33485<br>(10.35392) | .75855<br>(.010675) | .996 |
| (14.12) | 12 | -0.005127<br>(.007177) | .75402<br>(.00001392) | .999 |
| (14.13) | 13 | -.004861<br>(.0020049) | .10026<br>(.00000058) | .999 |

Government expenditure function:

(15) $$G_{ij} = \underset{(10.1457)}{55.2434} + \underset{(0.007116)}{0.92961}T \qquad R^2 = 0.998$$

# APPENDIX C

# THE APCO REGIONAL ECONOMIC MODEL SYSTEM (PHASE III)

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The APCO Regional Economic Model developed in three years (Phase III) by CONSAD is a logical extension of the concepts and empirical work of the first two years into an operational tool amenable to assessment of various control strategies. In particular, it builds on and extends in Phase II 31 AQCR model (Appendix B) in three important dimensions.

First, the Phase III model is extended to cover 100 AQCR's. These 100 AQCR's account for over 65% of the nation. Thus, the APCO model will cover a major portion of the economic activity in the nation.

Second, the Phase III model overcomes a major drawvack of the 31 AQCR model, which treats each AQCR as an isolated region. In reality, economic effects are attendant on pollution abatement. Strategies such as price increases in certain industries, the growth of control equipment industries or demand spurred by reduced expenditures on health, etc., in one region will have feedback affects on the economies of other regions. The Phase III APCO Economic Model system uses a national input-output system linked to a regional market share matrix to capture these interregional feedback effects and encompasses the 100 AQCR's as an interrelated system of regions.

Third, the Phase III model incorporates a regional fuel demand submodel as a component of the Regional Economic Model system. As air pollution control policy is implemented, sulfur content in coal and fuel oils will greatly affect their price in view of increased demand for low sulfur fuels and their limited supply. Prices of natural gas and electricity will also tend to change. Industries will choose an optimal combination of fuels and electricity which minimizes the total cost of energy to the degree substitution is possible. The fuel demand model will describe these relationships.

This appendix is addressed in particular to the description of the incorporation of the interregional feedbacks and regional fuel demand model into the APCO Regional Economic Model system. The rest of the model system represents an extension of the 31 AQCR model to the 100 AQCR's.

## 1. I-O System and Interregional Feedback

As emphasized earlier in the model formulation, a region's growth is closely dependent upon its capability to carry on external trade with other regions. A national input-output system is introduced to serve the role of external market for the regional economy described in the regional model, and also, hopefully, to measure the structural change of the national economy upon air pollution control to the 100 AQCR's.

The input-output system has been one of the most popular approaches used in economic structure analysis in the past several decades. With sufficient knowledge in input-output coefficients and details of the final demand, levels of interindustrial demand can be derived by its inverse matrix. However, one major weakness of the input-output system is that its operational feasibility is solely dependent upon exogeneous information regarding final demand. Therefore, a combined structure of the Keynsian macro-economic system and input-output table has been introduced in some recent econometric model development.* A modification of Klein's formulation will be summarized as follows.* The input-output system will be

---

* For example, Dusenberry, J. S., Fromm, G., Klein, L. R., and Kuh, E. (eds.), The Brookings Quarterly Econometric Model of the United States, 1965, Chapter 17.

$$(I - A) X = Y$$

where:

X is a vector of industry outputs

Y is a vector of final demand by sector

A is a matrix of technical coefficient

I is a unit matrix

In this model, aggregation of sectoral demand (the elements of Y) is equal to GNP.

$$\sum_{i=1}^{n} Y_i = GNP$$

This approach can be viewed as a model system when those sector demands are explained in terms of Engel curves or its analogues are related to the Keynsian type macro-economic system.

The relation between a national input-output system and a cross-sectional regional model of Keynsian type formulation can be better explained from policy questions to be answered from this model system. The regional model developed in Phase II is appropriate for an isolated

---

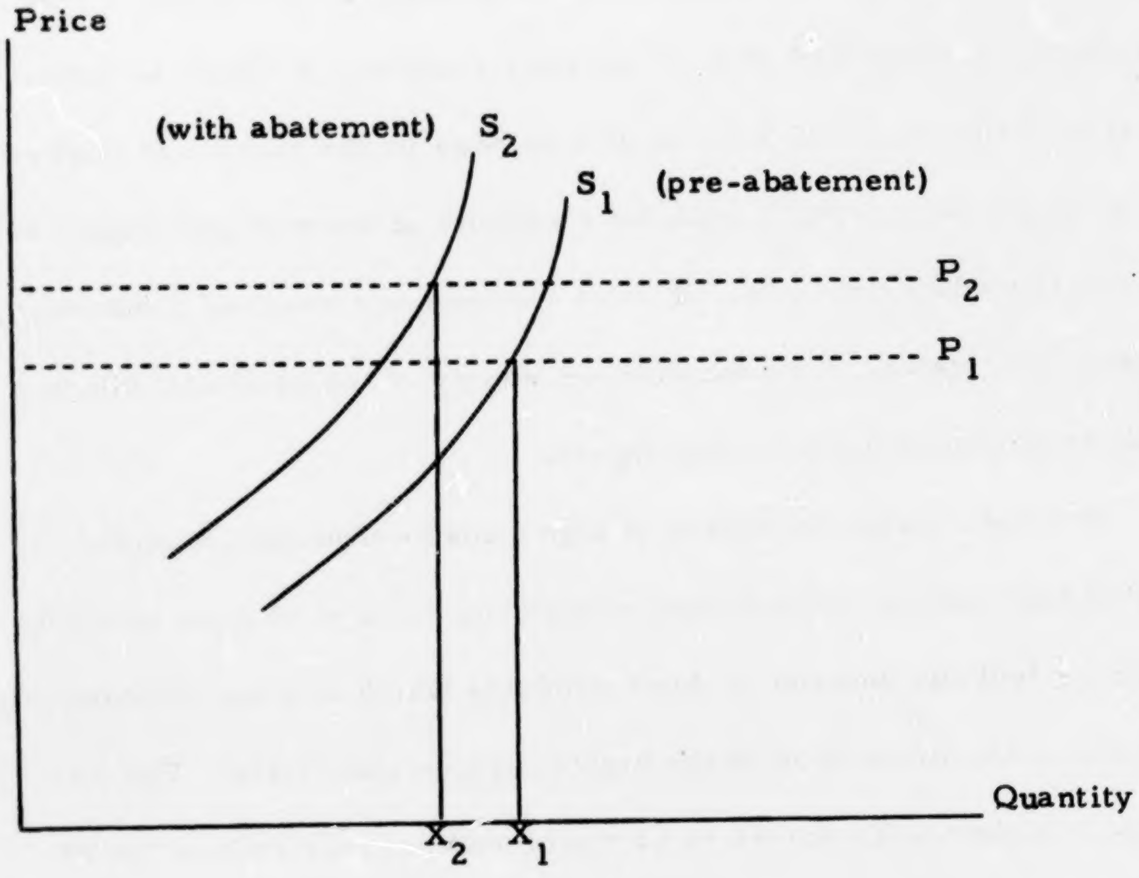
** Klein, Lawrence R., "What Kind of Macro-Econometric Model for Developing Economies?", Econometric Annual of the Indian Economic Journal, Volume 13, No. 3, 1965, also reprinted in A. Zellner (ed.), Readings in Economic Statistics and Econometrics, 1968.

region without interregional feedback scheme, although the export activity is explicitly treated. When an air pollution control policy is implemented across the nation, costs of production increases. This will result in an upward shift of the supply curve. Whether an industry or an individual firm may be able to pass on the increased cost per unit of output is dependent upon the elasticity of demand and supply of the corresponding products. If price changes are obtained from exogeneous information,* the equilibrium supply of the products will be known as shown in the following figure.

However, price increases in high emission industries under air pollution control will not only reduce the demand of their products but also effect the demand of those products which are the intermediate products in the production of the high emission industries. For example, a higher price for steel products will not only reduce the demand for steel but also affect sales in transportation, coal products, and other materials and services related to the steel industry. Further, such effects originating in a given region (or AQCR) in the nation will not be limited to the region but would affect the economic

---

* A study of price markup which air pollution control is instituted has been reported in LeSourd, D. A. etc., Comprehensive Study of Specified Air Pollution Sources to Assess the Economic Effects of Air Quality Standards, Research Triangle Institute, December, 1970.


Price
(with abatement) $S_2$
$S_1$ (pre-abatement)
$P_2$
$P_1$
Quantity
$X_2$
$X_1$

activity in other regions (AQCR's) and in all likelihood, create a feedback to the region.*

For a limited number of regions, the formulation of an interregional I-O system is perhaps feasible. However, a 20 sector regional I-O system with 100 regions, the size of the matrix will be 2000 x 2000 (with such detailed information largely nonexistent).

An alternative formulation was consequently necessary. A national input-output system linked to a regional market share matrix was used to capture the regional feedback. It is argued that the regional share of the national market by industry (termed as the "location quotient") is relatively stable. For example, if steel production in Pittsburgh AQCR is 12% of the nation's steel product, a change in the national steel market will have a 12% effect on the Pittsburgh AQCR. This concept is particularly useful for a cross-sectional model which deals with the geographic distribution of economic activity at a given period of time.

In brief, using exogeneous information on price changes in high emission industries occasioned by air pollution control, the high emission industries in each air quality control region (AQCR) will fall in output to the point corresponding to an upward shifting supply curve and the new price after control. An aggregation of changes in regional production for each high emission industry will give the change of demand in the nation. By use of the national input-output system, the impact of changes in high emission industries on other industries can be measured. Finally, through the use of regional market share matrix, the national impact can be distributed to each region (AQCR) as the net interregional feedback from the other regions under study (99 AQCR's) and the rest of the nation.

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* These interregional feedback phenomenon were observed in a pioneer study by Ronald E. Miller, "Interregional Feedback Effects in Input-Output Models: Some Preliminary Results," Paper, Regional Science Association, Vol. 17, 1966.

Mathematically, high emission industry in each region will have an exogeneous determined price equation and supply curve as follows.

$$P_j = \bar{P}_j \quad \text{(exogeneous price determination of industry j)}$$

$$Q_{ij} = f(P_j, \text{ factor prices, etc.}) \quad \text{(regional supply curve of high emission industry j in region i)}$$

Price increase after air pollution control, $\Delta P_j$, will determine change of production $\Delta Q_{ij}$ with other factors of the regional supply curve of industry j in region i.

Aggregation of $\Delta Q_{ij}$, over regions (say 100 AQCR's) under control will give the "national" change of the demand (supply = demand at equilibrium in each region).

$$\Delta Y_j = \sum_{i=1}^{m} \Delta Q_{ij} \qquad j = 1, \ldots n$$

Change of final demand by high emission sectors, $\Delta Y_j$, will affect the structure change of the national economy since

$$(i - A) \Delta X = \Delta Y$$

then

$$\Delta X = (I - A)^{-1} \Delta Y$$

$\Delta X$ is a vector of change in gross product by sector in the nation as the results of air pollution control are implemented, say in 100 AQCRs. $\Delta X$ is then distributed to each region with the regional market share matrix B. B is an nxm matrix.

$$B = [b_{ij}] \qquad \begin{array}{l} i=j, \ldots m \\ j=1, \ldots n \end{array}$$

By definition,

$$b_{ij} = \frac{X_{ij}}{X_j}$$

where

$b_{ij}$ is the regional market share of jth industry product in the ith region

$X_{ij}$ is the output of the jth industry in the ith region

$X_j$ is the output of jth industry in the nation

Appendix D provides the empirical development of the input-output model system and the interregional feedback formulated here.

## 2 Regional Fuel Demand Model

It has been observed that the burning of coal, fuel oil and natural gas to produce power and heat is one of the most important sources of particulates, sulfur oxides, and nitrogen emission to the air. Coal. coke, fuel oil, natural gas and electricity are also the most important energy sources available to the manufacturing industries in the nation. Demand for energy increases as the manufacturing output increases. However, each type of manufacturing industry differs from the other in the production process; therefore, the type of fuels and combination of different type of fuel and electric power also differ from industry to industry.

On the other hand, it is true that there are substitutional relations among the different types of fuel and/or electricity to produce the energy (power and heat) necessary for any given level of product of an industry. Hence, industry may choose an optimal combination of fuels and electricity which minimizes the total cost of energy. This is to say, the prices of fuels and electricity also affect the demand for each type of fuel or amount of electricity in the production process of each type of manufacturing industry. Therefore, if the price of electricity or any type of fuel changes, then the demand for the fuels and electricity changes according to a new optimal combination which minimizes the total cost of the energy.

As the air pollution control policy is implemented, sulfur content in coal and fuel oils will greatly affect the price because of increased demand for low sulfur fuels and their limited supply. Prices of natural gas and electricity (partly by the increase in production cost) tend to change because of changes in demand and supply relations.

Demand for energy, and hence fuels, like the demand for labor or capital is an induced demand from moderation. Therefore, an appropriate way to incorporate an energy demand model into the regional model would be to reformulate the production functions in the regional model.

A production function describes the maximum output obtainable from every possible combination of inputs. Some of the inputs are substitutable for one another while others are non-substitutable and are proportional to the output. A general production relation can be conceived of various type of inputs, with substitutional relations among a group of inputs categoried into a number of sub-groups. Between any pair of sub-groups of inputs there is no substitutional relation. Further assume that inputs for a given industry have been classified into 3 groups of inputs. Since there is no substitutional relations among those 3 inputs, the productions function can be given as

$$X = \min \left(\frac{1}{a_1} X_1, \frac{1}{a_2} X_2, \frac{1}{a_3} X_3\right)$$

Each group input is proportionate to the output. However, within each group of inputs there are substitutional relations

$$X_i = f(x_{i1}, x_{i2}, \ldots x_{in}) \qquad i=1, 2, 3$$

$f$ has all properties of a new-classical production function. Therefore,

$$X = \min\left[\frac{1}{a_1} f_1(x_1 \ldots x_{n_1}), \frac{1}{a_2} f_2(x_{n_1+1}, \ldots x_{n_2}), \frac{1}{a_3} f_3(x_{n_3+1}, \ldots x_n)\right]$$

In the Phase II model, the production functions treated the relation between value added as output, and labor and capital as inputs in the form of a Cobb-Douglas type function. Consequently, intermediari products included in the production were omitted as explicit factors of production.

Assume that X is gross product (or value of shipments) of a given industry, V is its value-added, Z is energy requirement in this production, M is another intermediate good. *

$$X = \min\left[\frac{1}{a_1} V, \frac{1}{a_2} Z, \frac{1}{a_3} M\right]$$

Thus we can derive the relation between value-added and total energy as

$$Z = \frac{a_2}{a_1} V$$

i.e., energy demand is proportionate to the value-added.

---

* Although M can be an aggregation of other intermediate goods,

Suppose there are five types of fuels $E_i$ (i=1, . . . , 5), the technical relations between fuels as inputs and total energy produced can be described as an energy production function which is similar to the relation between labor and capital to the value-added.

$$Z = f(E_1, \dots, E_5)$$

This relation provides the substitutional relation between each pair of $E_i$ with a given level of energy (Z).

As shown in Figure 1, with a given level of energy, there are various combinations of fuel which produce the same level of energy. For example, in Figure 1 combination of $E_1'$ and $E_2'$ gives the same energy as combination of $E_1''$ and $E_2''$ .

Given the price of each type of fuel i(i=1, . . . , 5), total cost of energy, C, is the sum of the cost of all types of fuel which is product of price and quantity of fuel

$$C = C_1 + C_2 + C_3 + C_4 + C_5$$
$$= q_1 E_1 + q_2 E_2 + q_3 E_3 + q_4 E_4 + q_5 E_5$$

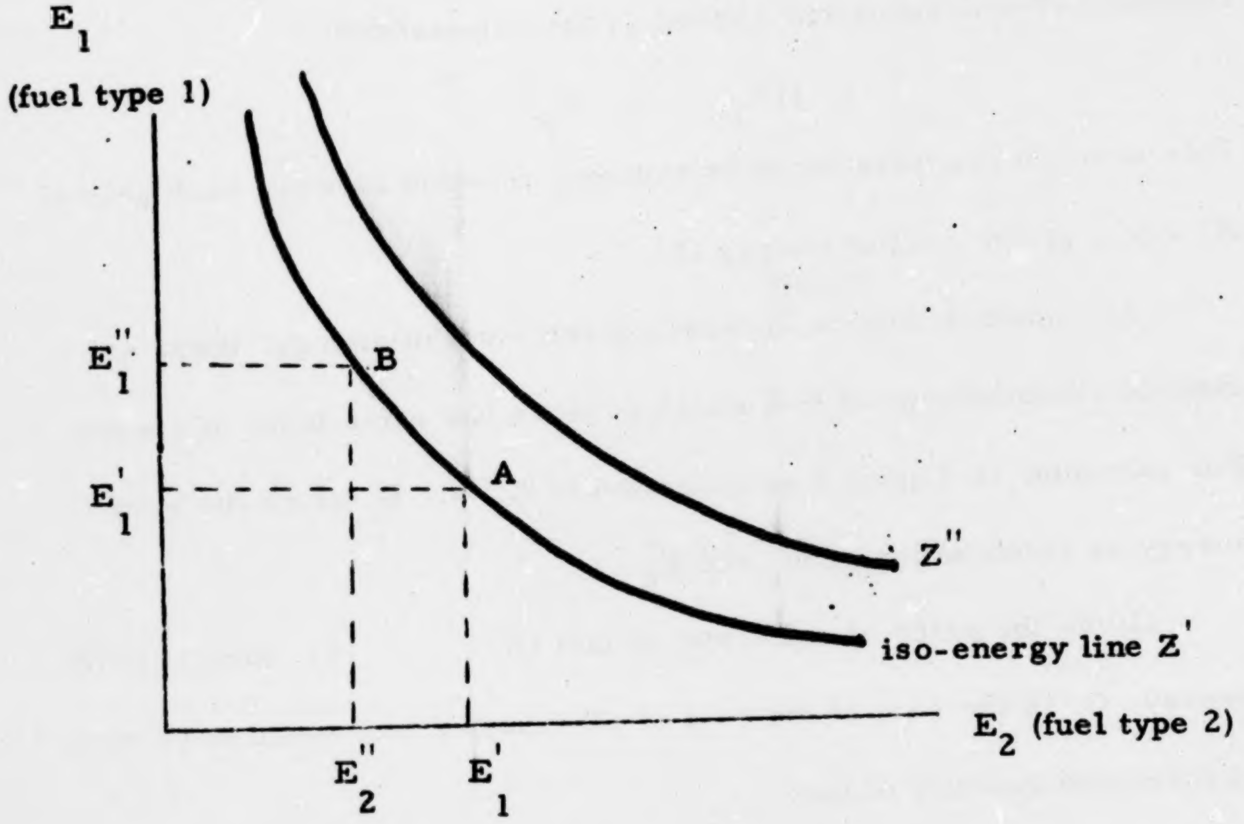
where

$C_i$ (i = 1, . . . , 5) is cost of fuel type i,

$q_1$ (i = 1, . . . , 5) is price of fuel type i,

$E_i$ (i = 1, . . . , 5) is quantity of fuel type i.

FIGURE 1
FUEL SUBSTITUTION: ISO-ENERGY LINE


$E_1$
(fuel type 1)
$E_1''$
B
A
$E_1'$
$Z''$
iso-energy line $Z'$
$E_2$ (fuel type 2)
$E_2''$
$E_1'$

Given the cost function C and energy production function E, the optional behavior for an industry will be:

$$\text{Minimize cost} \quad C = \sum_{i=1}^{5} q_i E_i$$

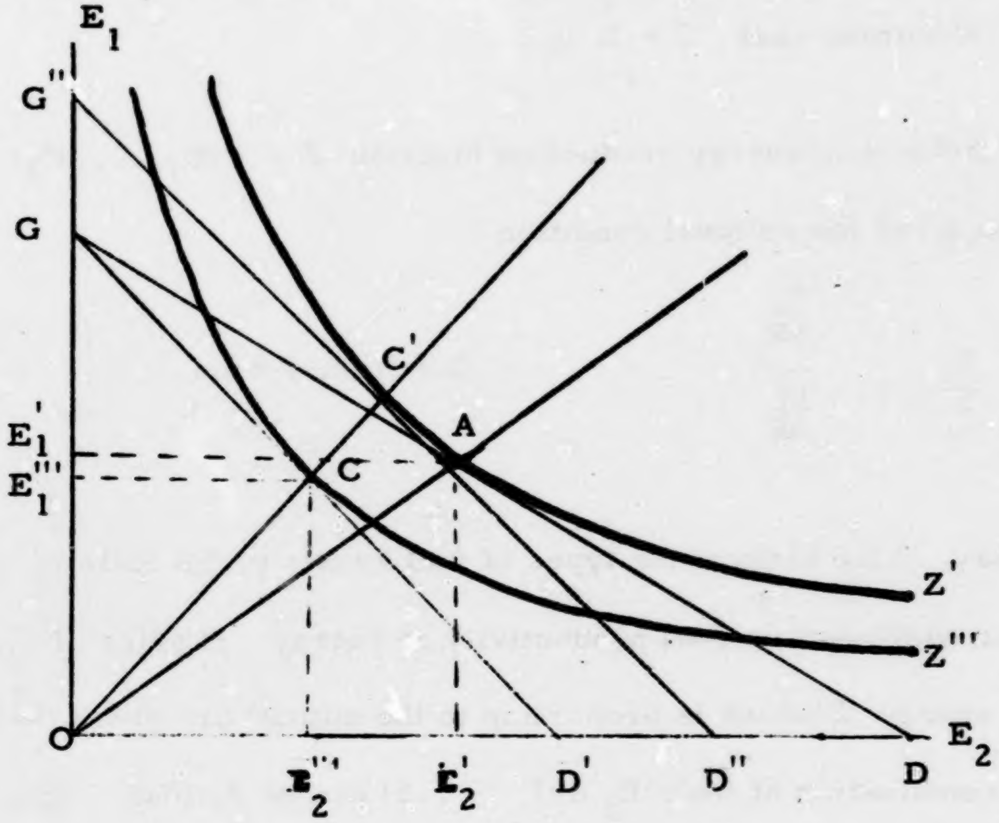
$$\text{Subject to energy production function} \quad Z = f(E_1, \ldots, E_5)$$

The solution gives the optional condition.

$$\frac{q_i}{q_j} = \frac{\frac{\partial f}{\partial E_i}}{\frac{\partial f}{\partial E_j}} \qquad (i \neq j), \ i, \ j = 1, \ldots, 5$$

That is to say, price ratio of the types of fuel equals to the ratio of marginal (or additional unit of) productivity of energy. If price of fuel $q_i$ and total energy Z(which is proportion to the output) are given then as optimal combination of fuels $E_i$ $(i=1 \ . \ . \ . , 5)$ can be divided. This relation can better be explained in the following figure

FIGURE 2
DETERMINATION OF OPTIMUM FUEL COMBINATIONS


E1
G''
G
E1'
E1'''
C'
A
C
Z'
Z'''
O
E2
E2'''
E2'
D'
D''
D

### 3. The Regional Model

With interregional relations and fuel demand submodel being formulated as indicated above, the rest of the Phase III model is quite similar to that of Phase II 31 AQCR regional model.

Notation:

| | |
|---|---|
| $V_{ij}$ | value-added by industry j of ith AQCR |
| $K_{ij}$ | capital stock by industry j of ith AQCR |
| $N_{ij}$ | employment by industry j of ith AQCR |
| $I_{ij}$ | investment expenditure by industry j of ith AQCR |
| $\Pi_{ij}$ | capital share or gross profit by industry j of ith AQCR |
| $W_{ij}$ | average wage by industry j of ith AQCR |
| $Y_i$ | regional personal income of ith AQCR |
| $C_i$ | regional consumption expenditure of ith AQCR |
| $G_i$ | local government expenditure of ith AQCR |
| $T_i$ | local government revenue of ith AQCR |
| $\overline{N}_i$ | employment by industries other than manufacturing industries of ith AQCR |
| $N_i$ | $= (\sum_{j=1}^{19} N_{ij} + \overline{N}_i)$ total regional employment of ith AQCR |
| $L_i$ | regional labor force of ith AQCR |
| $Q_i$ | total regional consumption of electric power in ith AQCR |

| | |
|---|---|
| $Q_{ij}$ | electric power consumed by industry j of ith AQCR |
| $Q_{ci}$ | electricity consumed by residents of ith AQCR |
| $\overline{Q}_i$ | electricity consumed by industries other than manufacturing industries of ith AQCR |
| $q_r$ | price of fuel type r of ith AQCR, type of fuel including coal, coke, fuel oil and natural gas |
| $E_{rij}$ | demand of fuel, type r by jth industry by ith AQCR |
| $i = 1, \ldots, 100$ | 100 AQCR's |
| $j = 1, \ldots, 19$ | which is two-digit manufacturing industries |

The sector structure of the manufacturing industries included two digit SIC industries as follows.

MANUFACTURING INDUSTRY CODE

| SIC | Industry |
|---|---|
| 20 | Food and kindred products |
| 22 | Textile mill products |
| 23 | Apparel and related products |
| 24 | Lumber and wood products |
| 25 | Furniture and fixtures |
| 26 | Paper and allied products |
| 27 | Printing and publication |
| 28 | Chemicals and allied products |
| 29 | Petroleum and coal products |
| 30 | Rubber and plastics products |
| 31 | Leather and leather products |
| 32 | Stone, clay, and glass products |
| 33 | Primary metal industries |
| 34 | Fabricated metal products |
| 35 | Machinery, except electrical |
| 36 | Electrical machinery |
| 37 | Transport equipment |
| 38 | Instruments and related products |
| 39 | Miscellaneous products |

For manufacturing industry in each AQCR, the following equations provide a submodel of manufacturing sectors.

$$(1) \quad V_{ij}(t) = A_{ij} N_{ij}^{\alpha j}(t) K_{ij}^{1-\alpha_j}(t) \qquad j=1, \ldots, 19$$

$$(2) \quad \Pi_{ij}(t) = (1 - \alpha_j) V_{ij}(t) \qquad j=1, \ldots, 19$$

$$(3) \quad I_{ij}(t) = f(\Pi_{ij}(t), K_{ij}(t-1)) \qquad j=1, \ldots, 19$$

$$(4) \quad K_{ij}(t) = K_{ij}(t-1) + I_{ij}(t) - d_j K_{ij}(t) \qquad j=1, \ldots, 19$$

$$(5) \quad W_{ij}(t) = f(W_{ij}(t-1), u_i(t)) \qquad j=1, \ldots, 19$$

Equation (1) is a typical Cobb-Douglas production function. Equation (2) states the profit as capital share from value-added. Equation (3) relates investment to the current profit and existing capital stock. Equation (4) is capital identity which defines capital stock of time t as capital stock of previous period plus new investment minus depreciation. $d_j$ is the depreciation rate by industry ($j = 1, \ldots, 19$).

Integration of Keynsian system and economic base theory can be treated in a regional income determination as before (Phase II).

$$(6) \quad Y_i(t) = f(C_i(t), \sum_j V_{ij}(t), G_i(t))$$

$$(7) \quad C_i(t) = f(Y_i(t), C_i(t-1))$$

$$(8) \quad G_i(t) = f(T_i(t))$$

In Equation (6), manufacturing industries are treated as export activity while regional consumption $C_i$ and local government expenditure also are included in income determination. Equation (7) is a typical consumption function, and Equation (8) merely relates local government expenditure to local government revenue.

Industries other than manufacturing industries have been treated as residual of regional economic activity. Therefore, the employment by industries other than manufacturing industries is related to the nonmanufacturing income in Equation (9).

$$(9) \quad \overline{N}_i(t) = f(Y_i(t) - \sum_j^{19} V_{ij}(t)$$

The labor market in each AQCR can be given by

$$(10) \quad N_i(t) = \overline{N}_i(t) + \sum_j^{19} N_{ij}(t) )$$

$$(11) \quad u_i(t) = \frac{L_i(t) - N_i(t)}{L_i(t)}$$

$$(12) \quad L_i(t) = f(N_i(t), u_i(t))$$

Electric power demands are vital to the air pollution control problem, it gives

(13) $Q_{ij}(t) = f(V_{ij}(t))$ $\qquad j=1, \ldots, 19$

(14) $Q_{ci}(t) = f(C_i(t))$

(15) $\overline{Q}_i(t) = f(Y_i(t) - \sum_j V_{ij}(t))$

(16) $Q_i(t) = \sum_j Q_{ij}(t) + Q_{ci}(t) + \overline{Q}_i(t)$

Electricity consumed by each economic sector is related to the level of production of manufacturing industries, consumption expenditure of residents, and income of other industrial sectors respectively. Equation (16) gives the total regional demand of electricity.

Fuel demand model developed in the previous section can be given as

(17) $\sum_r E_{rij} \cdot q_{ri} = a_j V_{ij}$ $\qquad j=1, \ldots, 19$

(18) $Z_{ij}(t) = B_{ij}(t) E_{1ij}^{\beta_{1j}}, E_{2ij}^{\beta_{2j}}, \ldots E_{5ij}^{\beta_{5j}}$ $\qquad j=1, \ldots, 19$

Equation (17) gives the relation that the cost of fuel in the production is proportionate to the value-added by industry in each AQCR. And Equation (19) is an energy production function for a given industry.

## 4. Statistical Estimations

This section provides the results of statistical estimation of 162 equations in the region component of the Model System.*

(1) Production functions

$$V_{ij} = A_j N_{ij}^{\alpha_j} K_{ij}^{1-\alpha} \qquad j=1, \ldots, 19$$

| Equation Number | SIC | $A_j$ | $\alpha_j$ | $1-\alpha_j$ | $R^2$ |
|---|---|---|---|---|---|
| (1.1) | 20 | 3.6408<br>(.2714) | .3846<br>(1.3488) | .6154 | .997 |
| (1.2) | 22 | 3.5518<br>(.5138) | .5614<br>(1.1609) | .4386 | .995 |
| (1.3) | 23 | 7.0735<br>(1.0456) | .5696<br>(1.1444) | .4304 | .998 |
| (1.4) | 24 | 3.8879<br>(.6094) | .5780<br>(1.1726) | .4220 | .988 |
| (1.5) | 25 | 5.4057<br>(.3146) | .5569<br>(1.3215) | .4431 | .997 |
| (1.6) | 26 | 3.3285<br>(.0830) | .5153<br>(1.1829) | .4847 | .994 |
| (1.7) | 27 | 5.6188<br>(.4513) | .5306<br>(1.1687) | .4694 | .995 |
| (1.8) | 28 | 2.4928<br>(.1923) | .2890<br>(1.5465) | .7110 | .994 |
| (1.9) | 29 | 1.2408<br>(.1455) | .2499<br>(1.6557) | .7501 | .994 |

---

* This count of equations does not include the I-O Model and the market share matrix of the Regional Model System.

| | | | | | |
|---|---|---|---|---|---|
| (1. 10) | 30 | 4. 1808<br>(. 4282) | . 5030<br>(1. 1932) | . 4970 | . 995 |
| (1. 11) | 31 | 6. 2163<br>(. 7523) | . 5423<br>(1. 1617) | . 4577 | . 995 |
| (1. 12) | 32 | 3. 4098<br>(. 3146) | . 4649<br>(1. 2411) | . 5351 | . 988 |
| (1. 13) | 33 | 3. 5046<br>(. 3079) | . 5156<br>(1. 1858) | . 4844 | . 998 |
| (1. 14) | 34 | 4. 9152<br>(. 3368) | . 5192<br>(1. 1801) | . 4808 | . 998 |
| (1. 15) | 35 | 5. 2706<br>(. 4248) | . 5257<br>(1. 1753) | . 4743 | . 995 |
| (1. 16) | 36 | 5. 9796<br>(. 5209) | . 5356<br>(1. 1665) | . 4644 | . 998 |
| (1. 17) | 37 | 6. 2431<br>(. 6891) | . 5726<br>(1. 1365) | . 4274 | . 998 |
| (1. 18) | 38 | 5. 7923<br>(. 6361) | . 5013<br>(1. 1999) | . 4987 | . 998 |
| (1. 19) | 39 | 5. 098<br>(. 4871) | . 5271<br>(1. 1718) | . 4729 | . 994 |

Given the Cobb-Douglas production function, capital share or gross profit can be derived as follows.

(2) $$\Pi_{ij} = (1 - \alpha_j) V_{ij} \qquad j=1, . . . , 19$$

Capital share coefficients, $(1 - \alpha_j)$, can be obtained as in the preceding table for the production function. Therefore, there are 19 equations (2. 1) through (2. 19).

(3) Investment function

$$I_{ij} = a_j + b_j \Pi_{ij} \qquad j=1, \ldots, 19$$

| Equation Number | SIC | $a_j$ | $b_j$ | $R^2$ |
|---|---|---|---|---|
| (3.1) | 20 | 2.1030<br>(1.047) | 0.084<br>(0.0050) | 0.799 |
| (3.2) | 22 | 0.1677<br>(0.1721) | 0.1068<br>(0.0044) | 0.934 |
| (3.3) | 23 | 0.8537<br>(0.6129) | 0.0265<br>(0.0035) | 0.478 |
| (3.4) | 24 | 0.4099<br>(0.4073) | 0.1111<br>(0.0382) | 0.119 |
| (3.5) | 25 | 0.6597<br>(0.4689) | 0.0725<br>(0.0174) | 0.222 |
| (3.6) | 26 | 2.8315<br>(1.7716) | 0.1502<br>(0.0348) | 0.229 |
| (3.7) | 27 | 2.6523<br>(0.6559) | 0.0585<br>(0.0027) | 0.869 |
| (3.8) | 28 | 1.6595<br>(2.0899) | 0.1042<br>(0.0093) | 0.670 |
| (3.9) | 29 | -1.1015<br>(2.1012) | 0.2979<br>(0.0205) | 0.853 |
| (3.10) | 30 | 3.6158<br>(3.6618) | 0.2204<br>(0.0784) | 0.117 |
| (3.11) | 31 | 0.0728<br>(0.0671) | 0.0342<br>(0.0028) | 0.778 |

|  |  |  |  |  |
|---|---|---|---|---|
| (3. 12) | 32 | 1. 0897<br>(0. 8574) | 0. 1564<br>(0. 0190) | 0. 506 |
| (3. 13) | 33 | -0. 5863<br>(1. 6544) | 0. 2715<br>(0. 0095) | 0. 933 |
| (3. 14) | 34 | -0. 0969<br>(0. 4430) | 0. 1260<br>(0. 0029) | 0. 967 |
| (3. 15) | 35 | 5. 1995<br>(6. 5116) | 0. 1343<br>(0. 0320) | 0. 216 |
| (3. 16) | 36 | 1, 8848<br>(1. 1608) | 0. 1116<br>(0. 0063) | 0. 844 |
| (3. 17) | 37 | 1. 1828<br>(1. 2960) | 0. 1122<br>(0. 0043) | 0. 922 |
| (3. 18) | 38 | -0. 0229<br>(0. 1575) | 0. 1076<br>(0. 0012) | 0. 992 |
| (3, 19) | 39 | 0. 1637<br>(0. 3164) | 0. 0715<br>(0. 0028) | 0. 917 |

(4) Capital Stock Identity

$$K_{ijt} = K_{ijt-1} + I_{ijt} - d_j K_{ijt} \qquad j=1, \ldots, 19$$

where $d_j$ is depreciation rate in industry j.

| Equation Number | SIC | Depreciation Rate $d_j$ |
|---|---|---|
| (4. 1) | 20 | .06738 |
| (4. 2) | 22 | .05248 |
| (4. 3) | 23 | .09060 |
| (4. 4) | 24 | .09149 |

| | | |
|---|---|---|
| (4.5) | 25 | .07366 |
| (4.6) | 26 | .05343 |
| (4.7) | 27 | .06859 |
| (4.8) | 28 | .06690 |
| (4.9) | 29 | .06139 |
| (4.10) | 30 | .06182 |
| (4.11) | 31 | .07549 |
| (4.12) | 32 | .06457 |
| (4.13) | 33 | .05598 |
| (4.14) | 34 | .06995 |
| (4.15) | 35 | .07216 |
| (4.16) | 36 | .07379 |
| (4.17) | 37 | .07840 |
| (4.18) | 38 | .06714 |
| (4.19) | 39 | .07321 |

(5) Regional Income Equation

$$\underset{(.0564)}{Y_i = .42836} \sum_{j=1}^{19} V_{ij} + \underset{(.06611)}{.94812\,C_i} + \underset{(.30932)}{2.8304\,G_i} \qquad R^2 = .997$$

(6) Regional Consumption Function

$$C_i = \underset{(50.09)}{137.99} + \underset{(.0057)}{.6133\,Y_i} + \underset{(.0012)}{.01214\,C_{it-1}} \qquad R^2 = .992$$

(7) Local Government Expenditure

$$G_i = 23.4227 + .94215T \qquad R^2 = .998$$
$$(4.108) \qquad (.0048)$$

(8) Employment by industries other than manufacturing industries

$$\overline{N}_i = 56.3560 + .10323\,(Y_i - \sum_{j=1}^{19} V_{ij}) \qquad R^2 = .978$$
$$(9.523) \qquad (.0016)$$

(9) Total employment

$$N_i = \overline{N}_i + \sum_{j=1}^{19} N_{ij}$$

(10) Labor force supply function

$$L_i = -13.958 + 1.0392\, N_i + 361.374\, U_i \qquad R^2 = .999$$
$$(2.080) \qquad (.0009) \qquad (55.965)$$

(11) Regional Unemployment Rate

$$U_i = \frac{L_i - N_i}{L_i} \times 100$$

(12) Electric power demand function by industry

$$Q_{ij} = a + b\, V_{ij} \qquad j=1, \ldots, 19$$

| Equation Number | SIC | $a_j$ | $b_j$ | $R^2$ |
|---|---|---|---|---|
| (12.1) | 20 | 1.4987<br>(.6969) | .006517<br>(.00024) | .918 |
| (12.2) | 22 | 1.4681<br>(.7354) | .009954<br>(.00109) | .667 |
| (12.3) | 23 | -.01340<br>(.0931) | .002932<br>(.000030) | .994 |
| (12.4) | 24 | .025681<br>(.1584) | .009854<br>(.00065) | .809 |
| (12.5) | 25 | .05072<br>(.07771) | .004665<br>(.00015) | .943 |
| (12.6) | 26 | 1.9802<br>(1.6883) | .01484<br>(.00212) | .457 |
| (12.7) | 27 | 1.0508<br>(.3265) | .002547<br>(.00010) | .913 |
| (12.8) | 28 | 12.0593<br>(5.492) | .0120<br>(.0022) | .329 |
| (12.9) | 29 | 2.00296<br>(2.5082) | .0325<br>(.01533) | .7971 |
| (12.10) | 30 | -.3307<br>(.3239) | .01533<br>(.00045) | .958 |
| (12.11) | 31 | .07498<br>(.0530) | .00308<br>(.00012) | .939 |
| (12.13) | 32 | 3.1259<br>(1.3261) | .01581<br>(.0018) | .549 |
| (12.14) | 33 | 8.8908<br>(6.1280) | .02730<br>(.0021) | .749 |

| | | | | |
|---|---|---|---|---|
| (12.14) | 34 | .2557<br>(.5316) | .0074<br>(.00025) | .938 |
| (12.15) | 35 | .6298<br>(.6848) | .005378<br>(.00023) | .902 |
| (12.16) | 36 | 2.08744<br>(1.1652) | .00547<br>(.00038) | .796 |
| (12.17) | 37 | -.2536<br>(1.3973) | .007513<br>(.00026) | .939 |
| (12.18) | 38 | .6778<br>(.3588) | .002845<br>(.00024) | .728 |
| (12.19) | 39 | .7320<br>(.7793) | .006066<br>(.00075) | .540 |

Electricity demand by residentials in each AQCR

(13) $$Q_{ci} = \underset{(.00216)}{.04718}\,C \qquad R^2 = .880$$

Electricity demand by other industries in each AQCR

(14) $$\overline{Q}_i = \underset{(.00423)}{.07947}\,(Y_i = \sum_j V_{ij}) \qquad R^2 = .846$$

Regional demand of electricity

(15) $$Q_i = \sum_{j=1}^{19} Q_{ij} + Q_{ci} + \overline{Q}_i$$

**Energy demand function**

(16) $Z_{ij} = a_j V_{ij}$ $j = 1, \ldots, 19$

| Equation Number | Industry SIC | $a_j$ |
|---|---|---|
| (16.1) | 20 | 2.13525 |
| (16.2) | 22 | 3.04152 |
| (16.3) | 23 | 0.74246 |
| (16.4) | 24 | 2.57780 |
| (16.5) | 25 | 1.33572 |
| (16.6) | 26 | 3.97124 |
| (16.7) | 27 | 0.61895 |
| (16.8) | 28 | 2.79554 |
| (16.9) | 29 | 9.43424 |
| (16.10) | 30 | 2.83225 |
| (16.11) | 31 | 1.15811 |
| (16.12) | 32 | 6.14368 |
| (16.13) | 33 | 10.68980 |
| (16.14) | 34 | 2.10111 |
| (16.15) | 35 | 1.34915 |
| (16.16) | 36 | 1.19740 |
| (16.17) | 37 | 1.35564 |
| (16.18) | 38 | 1.00903 |
| (16.19) | 39 | 1.44677 |

Energy production function

$$(17) \qquad Z_{ij} = B_j \, E_{1ij}^{\gamma 1j} \, E_{2ij}^{\gamma 2j} \, E_{3ij}^{\gamma 3j} \, E_{4ij}^{\gamma 4j} \, E_{5ij}^{\gamma 5j} \qquad j = 1, \ldots, 19$$

| Equation Number | SIC Code | $B_{ij}$ | $\gamma_1$ | $\gamma_2$ | $\gamma_3$ | $\gamma_4$ | $\gamma_5$ | $R_2$ |
|---|---|---|---|---|---|---|---|---|
| (17.1) | 20 | [illegible]7.304 | .0993 | .0 | .1107 | .2250 | .5651 | .984 |
| | | | (.0597) | | (.0687) | (.0908) | (.0820) | |
| (17.2) | 22 | [illegible]9.563 | .1133 | .0 | .1544 | .1070 | .6254 | .976 |
| | | (5.246) | (.0523) | | (.0786) | (.0429) | (.1204) | |
| (17.3) | 23 | 21.914 | .0 | .0 | .0934 | .0822 | .8244 | .998 |
| | | (7.570) | | | (.0572) | (.0359) | (.0817) | |
| (17.4) | 24 | 19.061 | .0 | .0 | .1707 | .1110 | .7183 | .970 |
| | | (3.693) | | | (.0337) | (.0323) | (.0493) | |
| (17.5) | 25 | 23.206 | .0882 | .0 | .0873 | .1243 | .7002 | .995 |
| | | (4.134) | (.0237) | | (.0282) | (.0280) | (.0618) | |
| (17.6) | 26 | 20.941 | .2150 | .0 | .1318 | .1378 | .5154 | .930 |
| | | (4.732) | (.1233) | | (.0961) | (.0995) | (.1390) | |
| (17.7) | 27 | 19.616 | .0 | .0 | .0670 | .1325 | .8006 | .982 |
| | | (1.963) | | | (.0206) | (.0352) | (.0503) | |
| (17.8) | 28 | 12.312 | .1564 | .0 | .0587 | .2067 | .5782 | .920 |
| | | (4.514) | (.0798) | | (.0618) | (.1109) | (.1352) | |
| (17.9) | 29 | 3.063 | .0 | .0 | .0620 | .5371 | .4009 | .959 |
| | | (.700) | | | (.0594) | (.1387) | (.1308) | |
| (17.10) | 30 | 14.935 | .0 | .0 | .1030 | .1236 | .7734 | .989 |
| | | (1.617) | | | (.0307) | (.0347) | (.0436) | |
| (17.11) | 31 | 17.965 | .1191 | .0 | .1535 | .1105 | .6169 | .941 |
| | | (12.313) | (.0318) | | (.0387) | (.0199) | (.0601) | |
| (17.12) | 32 | 9.586 | .1382 | .0 | .0818 | .3780 | .4020 | .857 |
| | | (2.476) | (.0785) | | (.0455) | (.1195) | (.0857) | |

|  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| (17.13) | 33 | 19.482 | .0465 | .1838 | .1062 | .2293 | .4342 | .983 |
|  |  | (4.450) | (.0195) | (.0852) | (.0546) | (.0701) | (.0982) |  |
| (17.14) | 34 | 17.059 | .0352 | .0 | .1108 | .2338 | .6202 | .993 |
|  |  | (1.719) | (.0173) |  | (.0588) | (.0762) | (.0691) |  |
| (17.15) | 35 | 19.981 | .0688 | .0 | .1087 | .1656 | .6569 | .987 |
|  |  | (2.734) | (.0363) |  | (.0663) | (.0597) | (.0687) |  |
| (17.16) | 36 | 16.827 | .0493 | .0 | .0800 | .1567 | .7139 | .955 |
|  |  | (2.912) | (.0142) |  | (.0391) | (.0436) | (.0556) |  |
| (17.17) | 37 | 17.572 | .0905 | .0 | .0717 | .1345 | .7032 | .990 |
|  |  | (5.738) | (.0321) |  | (.0406) | (.0394) | (.0536) |  |
| (17.18) | 38 | 18.982 | .1141 | .0 | .1159 | .1199 | .6500 | .969 |
|  |  | (8.577) | (.0591) |  | (.0226) | (.0197) | (.0593) |  |
| (17.19) | 39 | 20.846 | .0608 | .0 | .1289 | .1437 | .6666 | .985 |
|  |  | (4.008) | (.0182) |  | (.0436) | (.0661) | (.0980) |  |

# APPENDIX D

# INPUT-OUTPUT MODEL SYSTEM AND INTERREGIONAL FEEDBACK

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## 1. I-O Model

An input-output table of a nation shows the total output and the interindustry transactions in the national economy. The national economy is broken down into a large number of industries or sectors (up to more than 380 sectors in 1963 OBE Input-Output table) and represented in a matrix form. Each row provides the distribution of domestic outputs of a given industry to all other industries as intermediate products, and to the final demand for consumption. Each column represents the purchase of all inputs including intermediate products from all other industries and contribution of labor capital. The transactional patterns provided in an input-output table are assumed to be relatively stable regardless of level of output in each sector. The percentage distribution (or ratios) of inputs in a given column to one unit of output is called input-output coefficients which describe the present stage of production technology in a given industry. In this manner, the input-output table displays the pattern of the present stage of production technology of the nation. The input-output table is particularly useful when addressing the following type of policy. "If the final demand for goods and services changes, what would be the new gross domestic production in each industry?" Such information can be obtained through the use of so-called "inverse coefficient" matrix. The inverse matrix describes the direct and indirect input requirements of all sectors to deliver one unit of final demand.

As national air pollution control policies are implemented, the resulting cost increases in high emission industries would induce a price increase in the products of those industries. This increase in price may result in a reduction in the demands for the products of those industries. On the other hand, air pollution abatement would bring about cleaner air in the nation as a whole, leading in turn to a reduction in health expenditures, increase in property values, etc. These benefits can be viewed as additional money available to the United States residents for consumer expenditures which would create additional demand for a variety of goods and services.

Thus, the implementation of air pollution abatement policies in the nation will cause reduced demand for certain industries but the resulting benefits of cleaner air may stimulate the demand for products of the same or other industries. Such changes in demand and resulting outputs of various industries attendant upon an air pollution control policy can be ideally captured by the use of the national I-O model when it is properly sectored for the purpose at hand. Such a use of the model is explained in detail in the following section.

## 2. Use of the I-O Model

In order to provide an analytical tool for the study of national air pollution policies on the U. S. economic structure, CONSAD has developed a computer program entitled Program IOA (Input-Output Analysis). This program accepts as input a hundred sector input-output table and aggregates to any desired number of sectors. It also calculates the corresponding input-output coefficient table and inverse matrix. This program also takes changes of final demand by sectors and costs and benefits of national air pollution control policies to estimate the changes in production of each industry in the national economy.

To illustrate the use of this model, a 42-sector analysis has been conducted in this appendix. First, the total control costs by industry were transformed into the changes in the final demand in the nation.*

Second, the effects of benefit are estimated to be $1.5 billion of additional consumption expenditures to the national economy. This additional consumption expenditure is then distributed among 42-sectors to the consumption pattern of the nation; in other words, proportionally increase the sector consumption as before (this is average propensity to consume by sector). Sectoring of the I-O model, coefficient and inverse matrices are given in the following tables.

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* In this example, we use total control cost by industry provided in Comprehensive Economic Cost Study of Air Pollution Control Cost for Selected Industries and Selected Regions (February, 1970) by Research Triangle Institute to APCO. Control costs by sector are then transformed into changes of demands by the use of coefficients estimated in the regional model.

## Input-Output Coefficient Matrix and Inverse Matrix

### Sectoring of the Input-Output Model

| | | |
|---|---|---|
| SECTOR | 1 | AGRICULTURAL |
| SECTOR | 2 | IRON MINES |
| SECTOR | 3 | NON-FERROUS MINES |
| SECTOR | 4 | COAL MINES |
| SECTOR | 5 | CRUDE PETRO-NATURAL GAS |
| SECTOR | 6 | STONE AND CLAY MINING |
| SECTOR | 7 | CHEMICAL MINING |
| SECTOR | 8 | CONSTRUCTION |
| SECTOR | 9 | ORDINANCE (SIC 19) |
| SECTOR | 10 | FOOD PRODUCTS (SIC 20) |
| SECTOR | 11 | TOBACCO PRODUCTS (SIC 21) |
| SECTOR | 12 | TEXTILE PRODUCTS (SIC 22, 23) |
| SECTOR | 13 | LUMBER-WOODPRODUCTS (SIC 24) |
| SECTOR | 14 | FURNITURE-FIXTURES (SIC 25) |
| SECTOR | 15 | PAPER PRODUCTS (SIC 26) |
| SECTOR | 16 | PRINTING-PUBLISHING (SIC 27) |
| SECTOR | 17 | CHEMICAL PRODUCTS (SIC 28) |
| SECTOR | 18 | PETROLEUM REFINING (SIC 29) |
| SECTOR | 19 | RUBBER-PLASTIC PROD. (SIC 30) |
| SECTOR | 20 | LEATHER PRODUCTS (SIC 31) |
| SECTOR | 21 | STONE, CLAY,AND GLASS (SIC 32) |
| SECTOR | 22 | IRON AND STEEL MANU. (SIC 33) |
| SECTOR | 23 | COPPER MANUFACTURING (SIC 33) |
| SECTOR | 24 | ALUMINUM MANUFACTURE (SIC 33) |
| SECTOR | 25 | OTHER NON-FERROUS MET (SIC 33) |
| SECTOR | 26 | FABRICATED METAL PROD (SIC 34) |
| SECTOR | 27 | MACHINERY, EX. ELECTRIC (SIC 35) |
| SECTOR | 28 | ELECTIRCAL MACHINERY (SIC 36) |
| SECTOR | 29 | MOTOR VEHICLES (SIC 371) |
| SECTOR | 30 | OTHER TRANSPORTATION (SIC 37) |
| SECTOR | 31 | INSTRUMENTS (SIC 38) |
| SECTOR | 32 | MISCELLANEUS MANUFAC. (SIC 39) |
| SECTOR | 33 | TRANSPORTATION-WAREHOUSING |
| SECTOR | 34 | OTHER SERVICES |
| SECTOR | 35 | MEDICAL, EDUC. & NON-PROFIT |
| SECTOR | 36 | ELECTRIC UTILITIES (SIC 4911 |
| SECTOR | 37 | GAS UTILITIES (SIC 492) |

## Input-Output Coefficient Matrix and Inverse Matrix

## Sectoring of the Input-Output Model (continued)

| | | |
|---|---|---|
| SECTOR | 38 | WHOLESALE & RETAIL |
| SECTOR | 39 | FINANCE & SERVICES |
| SECTOR | 40 | IMPORT OF GOODS AND SERVICES |
| SECTOR | 41 | GOVERNMENT ENTERPRISES |
| SECTOR | 42 | MISCELLANEOUS BUSINESS |

Input/Output Coefficient Matrix

```
             COL  1     COL  2     COL  3     COL  4     COL  5     COL  6     COL  7     COL  8     COL  9
ROW  1    0.3063585  0.0        0.0        0.0        0.0        0.0        0.0        0.0028276  0.0
ROW  2    0.0        0.0665909  0.0088175  0.0        0.0        0.0002724  0.0006233  0.0        0.0
ROW  3    0.0        0.0311749  0.1529400  0.0        0.0        0.0005837  0.0005194  0.0        0.0
ROW  4    0.0001381  0.0044598  0.0009241  0.1821136  0.0000179  0.0017123  0.0008311  0.0000010  0.0
ROW  5    0.0        0.0        0.0        0.0        0.0263655  0.0        0.0018699  0.0000010  0.0
ROW  6    0.0012640  0.0        0.0000385  0.0004641  0.0        0.0070050  0.0151673  0.0100778  0.0
ROW  7    0.0005380  0.0        0.0008086  0.0000273  0.0        0.0003892  0.0639934  0.0        0.0
ROW  8    0.0123653  0.0005684  0.0008086  0.0008463  0.0003882  0.0012064  0.0005194  0.0001299  0.0015735
ROW  9    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0000459  0.0184039
ROW 10    0.0669180  0.0        0.0        0.0        0.0        0.0        0.0001039  0.0001563  0.0
ROW 11    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
ROW 12    0.0023912  0.0001312  0.0013092  0.0006825  0.0002090  0.0000389  0.0003117  0.0000840  0.0007553
ROW 13    0.0019046  0.0058590  0.0010011  0.0074254  0.0005793  0.0000389  0.0004155  0.0507102  0.0011959
ROW 14    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0064024  0.0000126
ROW 15    0.0008181  0.0000437  0.0003080  0.0026753  0.0004658  0.0096124  0.0055059  0.0052489  0.0047206
ROW 16    0.0002341  0.0000437  0.0002310  0.0002457  0.0000717  0.0002724  0.0        0.0001319  0.0017875
ROW 17    0.0225669  0.0127235  0.0294945  0.0174170  0.0047476  0.0118306  0.0312695  0.0215386  0.0034491
ROW 18    0.0174438  0.0093131  0.0056217  0.0108651  0.0046998  0.0272416  0.0088303  0.0181455  0.0021526
ROW 19    0.0032423  0.0005247  0.0023873  0.0078076  0.0032069  0.0187189  0.0042593  0.0054081  0.0236154
ROW 20    0.0000921  0.0        0.0        0.0        0.0000060  0.0        0.0        0.0000088  0.0000378
ROW 21    0.0005985  0.0007433  0.0047746  0.0023477  0.0004121  0.0649907  0.0005194  0.0707602  0.0036631
ROW 22    0.0        0.0170959  0.0360403  0.0084082  0.0002747  0.0141267  0.0177644  0.0333012  0.0134819
ROW 23    0.0        0.0000874  0.0001540  0.0004095  0.0000119  0.0000778  0.0002078  0.0052821  0.0073641
ROW 24    0.0        0.0000874  0.0001540  0.0000819  0.0000119  0.0000389  0.0002078  0.0003741  0.0142372
ROW 25    0.0000381  0.0017489  0.0047746  0.0064426  0.0007465  0.0011286  0.0031166  0.0171297  0.0287765
ROW 26    0.0024070  0.0021425  0.0016942  0.0118752  0.0061330  0.0007783  0.0017661  0.1041405  0.0190962
ROW 27    0.0042577  0.0247038  0.0250279  0.0501215  0.0144219  0.0706336  0.0348016  0.0193126  0.1096930
ROW 28    0.0005380  0.0021862  0.0036194  0.0032213  0.0038100  0.0019458  0.0043632  0.0252892  0.0693732
ROW 29    0.0011825  0.0005247  0.0007316  0.0021566  0.0008779  0.0039306  0.0021816  0.0000225  0.0041667
ROW 30    0.0004538  0.0022299  0.0        0.0042041  0.0        0.0001557  0.0003117  0.0000332  0.2121102
ROW 31    0.0        0.0002186  0.0003465  0.0000546  0.0000597  0.0002335  0.0002078  0.0031978  0.0238419
ROW 32    0.0000802  0.0        0.0        0.0012285  0.0000358  0.0003113  0.0002078  0.0018919  0.0025176
ROW 33    0.0163981  0.0997771  0.0316507  0.0073435  0.0254876  0.0158780  0.0597342  0.0313585  0.0104985
ROW 34    0.0641467  0.0764724  0.0338070  0.0278999  0.1597037  0.0365816  0.0196343  0.0506789  0.0201662
ROW 35    0.0030594  0.0007433  0.0007316  0.0009555  0.0008480  0.0008951  0.0008311  0.0009396  0.0009567
ROW 36    0.0027280  0.0139915  0.0144777  0.0227403  0.0047416  0.0215598  0.0208810  0.0020706  0.0029204
ROW 37    0.0003420  0.0008745  0.0054676  0.0000546  0.0016482  0.0017902  0.0203615  0.0000088  0.0006294
ROW 38    0.0337471  0.0194570  0.0244119  0.0328684  0.0124870  0.0603597  0.0248286  0.0879836  0.0288772
ROW 39    0.0096294  0.0053343  0.0114743  0.0096640  0.0097878  0.0106242  0.0058176  0.0081888  0.0063067
ROW 40    0.0203269  0.2990252  0.1587927  0.0010101  0.0822316  0.0592700  0.0891337  0.0        0.0018882
ROW 41    0.0001973  0.0007433  0.0009241  0.0012012  0.0004419  0.0015956  0.0010389  0.0002393  0.0009693
ROW 42    0.0009497  0.0044598  0.0038505  0.0040949  0.0063958  0.0049424  0.0082070  0.0038629  0.0202921
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            COL 10     COL 11     COL 12     COL 13     COL 14     COL 15     COL 16     COL 17     COL 18
ROW  1    0.3086993  0.1955482  0.0435766  0.1142030  0.0        0.0        0.0        0.0016479  0.0
ROW  2    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0023061  0.0002255
ROW  3    0.0        0.0        0.0        0.0000227  0.0        0.0        0.0        0.0018100  0.0
ROW  4    0.0006669  0.0002436  0.0006306  0.0001744  0.0004359  0.0057325  0.0        0.0041014  0.0006063
ROW  5    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0010806  0.5085889
ROW  6    0.0000480  0.0        0.0000020  0.0000152  0.0        0.0017786  0.0        0.0009578  0.0032976
ROW  7    0.0001243  0.0        0.0000315  0.0000076  0.0        0.0011649  0.0        0.0158431  0.0000665
ROW  8    0.0033984  0.0000530  0.0004927  0.0015015  0.0004480  0.0038579  0.0034071  0.0015472  0.0014824
ROW  9    0.0        0.0        0.0        0.0        0.0        0.0000919  0.0004181  0.0000049  0.0
ROW 10    0.1710971  0.0065455  0.0009242  0.0000076  0.0046615  0.0049017  0.0        0.0176605  0.0006913
ROW 11    0.0000075  0.1907821  0.0        0.0        0.0        0.0000084  0.0        0.0        0.0
ROW 12    0.0025205  0.0002012  0.4189151  0.0014863  0.0508888  0.0078911  0.0012735  0.0022300  0.0002736
ROW 13    0.0013931  0.0016523  0.0000532  0.2677022  0.1031579  0.0500813  0.0000481  0.0019082  0.0001664
ROW 14    0.0        0.0        0.0006602  0.0024418  0.0308868  0.0001169  0.0003844  0.0000049  0.0
ROW 15    0.0186234  0.0240106  0.0095339  0.0089254  0.0210554  0.2826012  0.1801769  0.0300801  0.0051867
ROW 16    0.0018951  0.0019594  0.0009045  0.0028892  0.0005085  0.0081040  0.1155335  0.0025222  0.0000370
ROW 17    0.0063447  0.0205896  0.0549413  0.0158337  0.0189728  0.0340194  0.0137917  0.2598557  0.0343695
ROW 18    0.0038100  0.0004448  0.0012415  0.0075225  0.0019857  0.0095278  0.0008458  0.0323150  0.0720884
ROW 19    0.0019045  0.0015146  0.0052872  0.0049215  0.0295187  0.0128095  0.0010716  0.0096272  0.0003734
ROW 20    0.0000057  0.0000424  0.0019687  0.0000607  0.0016830  0.0001253  0.0000481  0.0000147  0.0000037
ROW 21    0.0084461  0.0000106  0.0010503  0.0042163  0.0232953  0.0044424  0.0000144  0.0100987  0.0022662
ROW 22    0.0000245  0.0        0.0002168  0.0019868  0.0466269  0.0002129  0.0        0.0033523  0.0000222
ROW 23    0.0000207  0.0000212  0.0000138  0.0000152  0.0000363  0.0000084  0.0000144  0.0004224  0.0000333
ROW 24    0.0004380  0.0011650  0.0000296  0.0007962  0.0087297  0.0007766  0.0009995  0.0020556  0.0000333
ROW 25    0.0000876  0.0000212  0.0000769  0.0001896  0.0008233  0.0003006  0.0002547  0.0047719  0.0000739
ROW 26    0.0271165  0.0030609  0.0012829  0.0100326  0.0635898  0.0111394  0.0021144  0.0185078  0.0184398
ROW 27    0.0002618  0.0001165  0.0025126  0.0034883  0.0091777  0.0051229  0.0036810  0.0078049  0.0002773
ROW 28    0.0004728  0.0001059  0.0001360  0.0011754  0.0028332  0.0013945  0.0009323  0.0009382  0.0004695
ROW 29    0.0        0.0        0.0000315  0.0000455  0.0007991  0.0        0.0001538  0.0000123  0.0000148
ROW 30    0.0        0.0        0.0000512  0.0007432  0.0005933  0.0        0.0013359  0.0000393  0.0
ROW 31    0.0000019  0.0        0.0003015  0.0000152  0.0019978  0.0003298  0.0026190  0.0017633  0.0000776
ROW 32    0.0004606  0.0011333  0.0103143  0.0013043  0.0074099  0.0007933  0.0025854  0.0010241  0.0003586
ROW 33    0.0382386  0.0121801  0.0158340  0.0435503  0.0196388  0.0362698  0.0145510  0.0302422  0.0531975
ROW 34    0.0599993  0.0469408  0.0214346  0.0215514  0.0331994  0.0236816  0.0935868  0.0706838  0.0327836
ROW 35    0.0009306  0.0009850  0.0010168  0.0008797  0.0010170  0.0009645  0.0010668  0.0009603  0.0009464
ROW 36    0.0034389  0.0006355  0.0053010  0.0048381  0.0048310  0.0087261  0.0040270  0.0085368  0.0048946
ROW 37    0.0013328  0.0001589  0.0004178  0.0002806  0.0003753  0.0039664  0.0        0.0057616  0.0101145
ROW 38    0.0348505  0.0141818  0.0380115  0.0393720  0.0553566  0.0378856  0.0249357  0.0281178  0.0107023
ROW 39    0.0050128  0.0020547  0.0060695  0.0054144  0.0050368  0.0060331  0.0094428  0.0088217  0.0066395
ROW 40    0.0352716  0.0033998  0.0197497  0.0624325  0.0001332  0.0646193  0.0024700  0.0174149  0.0317337
ROW 41    0.0009155  0.0021500  0.0014287  0.0009782  0.0008839  0.0020208  0.0069631  0.0031902  0.0022625
ROW 42    0.0054838  0.0018535  0.0057405  0.0065670  0.0096014  0.0063003  0.0249212  0.0118547  0.0020739
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D8

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            COL 19     COL 20     COL 21     COL 22     COL 23     COL 24     COL 25     COL 26     COL 27
ROW  1    0.0        0.0003601  0.0003353  0.0        0.0        0.0        0.0        0.0        0.0001125
ROW  2    0.0        0.0        0.0007803  0.0524958  0.0        0.0        0.0065186  0.0        0.0000792
ROW  3    0.0        0.0        0.0008656  0.0002456  0.1268308  0.0339620  0.1005513  0.0001762  0.0
ROW  4    0.0016051  0.0006220  0.0071993  0.0218467  0.0012342  0.0016575  0.0008878  0.0002715  0.0003084
ROW  5    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
ROW  6    0.0005813  0.0        0.0457013  0.0025895  0.0010696  0.0002706  0.0000851  0.0001155  0.0003667
ROW  7    0.0012234  0.0002128  0.0022677  0.0003335  0.0        0.0000507  0.0003527  0.0000116  0.0
ROW  8    0.0009631  0.0001146  0.0004450  0.0059491  0.0003497  0.0005243  0.0001824  0.0006614  0.0010918
ROW  9    0.0        0.0000164  0.0        0.0000515  0.0        0.0        0.0003040  0.0002224  0.0005000
ROW 10    0.0001996  0.0007038  0.0007010  0.0003548  0.0002674  0.0        0.0        0.0000116  0.0000458
ROW 11    0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
ROW 12    0.0870933  0.0362211  0.0022921  0.0009127  0.0005348  0.0012008  0.0043538  0.0019465  0.0012522
ROW 13    0.0017353  0.0091494  0.0074005  0.0011704  0.0001234  0.0003383  0.0021161  0.0054324  0.0024315
ROW 14    0.0002256  0.0002619  0.0005303  0.0000728  0.0        0.0        0.0000122  0.0017993  0.0003438
ROW 15    0.0114788  0.0182006  0.0413610  0.0030837  0.0027563  0.0024186  0.0042565  0.0091580  0.0037837
ROW 16    0.0028892  0.0044683  0.0016825  0.0012098  0.0006788  0.0007949  0.0007419  0.0013632  0.0006938
ROW 17    0.1869843  0.0208194  0.0383313  0.0115070  0.0062531  0.0160338  0.0294552  0.0102642  0.0036003
ROW 18    0.0024207  0.0011785  0.0090525  0.0067951  0.0040727  0.0054123  0.0024201  0.0048346  0.0040045
ROW 19    0.0325971  0.0528668  0.0079735  0.0027259  0.0013781  0.0013362  0.0015080  0.0050310  0.0099384
ROW 20    0.0019695  0.2661997  0.0000975  0.0000030  0.0        0.0        0.0        0.0002310  0.0004417
ROW 21    0.0108281  0.0042883  0.1080201  0.0147242  0.0032088  0.0042960  0.0053997  0.0077949  0.0064173
ROW 22    0.0021951  0.0        0.0022921  0.2052591  0.0080015  0.0070698  0.0165275  0.2379037  0.0916253
ROW 23    0.0000087  0.0000491  0.0001219  0.0016161  0.2751155  0.0211924  0.0985325  0.0149803  0.0073757
ROW 24    0.0001822  0.0000491  0.0010790  0.0019285  0.0185330  0.2833830  0.0393303  0.0350379  0.0097905
ROW 25    0.0022385  0.0003437  0.0010302  0.0112524  0.0908755  0.0931586  0.1307119  0.0137096  0.0122574
ROW 26    0.0153658  0.0077909  0.0127527  0.0253610  0.0182039  0.0173531  0.0216475  0.0694693  0.0416623
ROW 27    0.0054488  0.0006220  0.0034869  0.0207096  0.0123828  0.0144778  0.0156275  0.0403952  0.1472430
ROW 28    0.0036961  0.0014240  0.0045232  0.0042208  0.0030648  0.0096068  0.0232285  0.0134525  0.0447334
ROW 29    0.0000174  0.0000491  0.0001463  0.0016738  0.0007611  0.0035180  0.0        0.0076389  0.0147222
ROW 30    0.0027851  0.0000818  0.0000975  0.0007944  0.0        0.0000677  0.0011918  0.0044967  0.0085987
ROW 31    0.0016051  0.0019805  0.0006218  0.0002820  0.0000617  0.0003214  0.0006446  0.0052794  0.0032399
ROW 32    0.0040258  0.0030771  0.0018715  0.0004730  0.0006994  0.0005412  0.0018607  0.0021025  0.0020981
ROW 33    0.0222375  0.0153526  0.0504988  0.0477566  0.0215361  0.0182833  0.0200300  0.0166179  0.0112573
ROW 34    0.0402409  0.0389708  0.0295592  0.0185174  0.0151185  0.0187907  0.0135722  0.0233066  0.0304029
ROW 35    0.0010498  0.0011948  0.0010180  0.0009248  0.0007611  0.0011839  0.0006324  0.0009444  0.0008813
ROW 36    0.0088586  0.0037645  0.0137951  0.0117890  0.0074667  0.0259112  0.0079171  0.0052851  0.0043004
ROW 37    0.0010238  0.0002619  0.0162213  0.0091207  0.0049778  0.0111797  0.0033323  0.0012765  0.0004084
ROW 38    0.0327967  0.0337496  0.0329973  0.0330657  0.0389996  0.0248288  0.0458853  0.0350523  0.0399621
ROW 39    0.0058912  0.0075454  0.0095889  0.0067951  0.0060268  0.0072727  0.0061902  0.0071624  0.0064756
ROW 40    0.0372823  0.0135686  0.0141182  0.0473745  0.1343592  0.0691248  0.1633776  0.0055335  0.0103281
ROW 41    0.0011540  0.0031589  0.0023957  0.0014130  0.0007611  0.0008457  0.0006081  0.0011726  0.0011793
ROW 42    0.0095180  0.0073326  0.0096865  0.0043390  0.0045047  0.0054968  0.0040741  0.0093631  0.0127574
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D9

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              COL 28     COL 29     COL 30     COL 31     COL 32     COL 33     COL 34     COL 35     COL 36
ROW  1      0.0        0.0        0.0        0.0007061  0.0020368  0.0010322  0.0177620  0.0004350  0.0
ROW  2      0.0005931  0.0        0.0        0.0        0.0        0.0        0.0000429  0.0        0.0
ROW  3      0.0003239  0.0        0.0        0.0006012  0.0        0.0        0.0000386  0.0        0.0002641
ROW  4      0.0002691  0.0006382  0.0003402  0.0004962  0.0001419  0.0008328  0.0004623  0.0000099  0.0286448
ROW  5      0.0        0.0        0.0        0.0        0.0        0.0        0.0008692  0.0        0.0000393
ROW  6      0.0000100  0.0000041  0.0000187  0.0000191  0.0001013  0.0000369  0.0000530  0.0        0.0000225
ROW  7      0.0        0.0        0.0        0.0        0.0        0.0000240  0.0000111  0.0        0.0000056
ROW  8      0.0010142  0.0028133  0.0013671  0.0002004  0.0027968  0.0358942  0.0500873  0.0305973  0.0334714
ROW  9      0.0106875  0.0002442  0.0389611  0.0192092  0.0000912  0.0        0.0014637  0.0        0.0000225
ROW 10      0.0        0.0000021  0.0        0.0019658  0.0013984  0.0029398  0.0006002  0.0079045  0.0000393
ROW 11      0.0        0.0        0.0        0.0        0.0001115  0.0        0.0000159  0.0000074  0.0000112
ROW 12      0.0016272  0.0109125  0.0019507  0.0091322  0.0260324  0.0013055  0.0044165  0.0048149  0.0001854
ROW 13      0.0022925  0.0005520  0.0085425  0.0007920  0.0203071  0.0007867  0.0002512  0.0001681  0.0002697
ROW 14      0.0098877  0.0002319  0.0043602  0.0028246  0.0011755  0.0        0.0008437  0.0038756  0.0000056
ROW 15      0.0128754  0.0043584  0.0012984  0.0202779  0.0578609  0.0012206  0.0467155  0.0141060  0.0012080
ROW 16      0.0009195  0.0004412  0.0006430  0.0004008  0.0046106  0.0019722  0.0015721  0.0002101  0.0002641
ROW 17      0.0149386  0.0069973  0.0070101  0.0218715  0.0379693  0.0025280  0.0052424  0.0249791  0.0011743
ROW 18      0.0018614  0.0018776  0.0028714  0.0016318  0.0027866  0.0429113  0.0069461  0.0027090  0.0162778
ROW 19      0.0155267  0.0250671  0.0067292  0.0092754  0.0320718  0.0068620  0.0009150  0.0        0.0004551
ROW 20      0.0003763  0.0002873  0.0001405  0.0013550  0.0131834  0.0001163  0.0001919  0.0001285  0.0000056
ROW 21      0.0164263  0.0122258  0.0063234  0.0133023  0.0076607  0.0002844  0.0017428  0.0003164  0.0013710
ROW 22      0.0406296  0.0836145  0.0572197  0.0148291  0.0273801  0.0011320  0.0001644  0.0        0.0020677
ROW 23      0.0076325  0.0032298  0.0021286  0.0064031  0.0078533  0.0000979  0.0000265  0.0        0.0002023
ROW 24      0.0102415  0.0052121  0.0142979  0.0093517  0.0105487  0.0002604  0.0000371  0.0        0.0005675
ROW 25      0.0353718  0.0025014  0.0102248  0.0221101  0.0343315  0.0012446  0.0004835  0.0        0.0000225
ROW 26      0.0445717  0.0626678  0.0429187  0.0306220  0.0307139  0.0018411  0.0016594  0.0009244  0.0078046
ROW 27      0.0285715  0.0296923  0.0539175  0.0310801  0.0076709  0.0044078  0.0098879  0.0001409  0.0006686
ROW 28      0.1659720  0.0222128  0.0394886  0.0561197  0.0142372  0.0042693  0.0067870  0.0009615  0.0006653
ROW 29      0.0032693  0.2960653  0.0087673  0.0094376  0.0010741  0.0027311  0.0094641  0.0000840  0.0000730
ROW 30      0.0049364  0.0011676  0.1609098  0.0119568  0.0026752  0.0136390  0.0026149  0.0009442  0.0001011
ROW 31      0.0115921  0.0043194  0.0131774  0.0617689  0.0012971  0.0008107  0.0052284  0.0140566  0.0000056
ROW 32      0.0017194  0.0007244  0.0015227  0.0040365  0.0578103  0.0014090  0.0049811  0.0012902  0.0003034
ROW 33      0.0131246  0.0184228  0.0114389  0.0116228  0.0158788  0.0628583  0.0056411  0.0054254  0.0337636
ROW 34      0.0397724  0.0343195  0.0159240  0.0420826  0.0448904  0.0762683  0.1005907  0.1178879  0.0202503
ROW 35      0.0010466  0.0009131  0.0009239  0.0009256  0.0010133  0.0009048  0.0013629  0.0133126  0.0007810
ROW 36      0.0046398  0.0033283  0.0043009  0.0030918  0.0045802  0.0032500  0.0055176  0.0125711  0.0606216
ROW 37      0.0004136  0.0006320  0.0006710  0.0002863  0.0        0.0003305  0.0010274  0.0045158  0.0277907
ROW 38      0.0398247  0.0293537  0.0272132  0.0470639  0.0657243  0.0289916  0.0224413  0.0189753  0.0152102
ROW 39      0.0041514  0.0037141  0.0035456  0.0051625  0.0083599  0.0201520  0.0232382  0.0118864  0.0056188
ROW 40      0.0061499  0.0329221  0.0057741  0.0232170  0.0528450  0.0319166  0.0015774  0.0002175  0.0012530
ROW 41      0.0026488  0.0017073  0.0010549  0.0014696  0.0019659  0.0252726  0.0199816  0.0013273  0.1388021
ROW 42      0.0187686  0.0041717  0.0064233  0.0189038  0.0132948  0.0054087  0.0080969  0.0237877  0.0039669
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D 10

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            COL 37       COL 38       COL 39       COL 40       COL 41       COL 42
ROW  1    0.0          0.0015527    0.0          0.0          0.0111706    0.0125010
ROW  2    0.0          0.0          0.0          0.0          0.0000336    0.0
ROW  3    0.0          0.0          0.0          0.0          0.0          0.0
ROW  4    0.0005441    0.0000498    0.0002397    0.0          0.0025558    0.0
ROW  5    0.1902156    0.0000027    0.0          0.0          0.0004505    0.0
ROW  6    0.0          0.0000375    0.0          0.0          0.0000069    0.0
ROW  7    0.0          0.0          0.0          0.0          0.0          0.0
ROW  8    0.0233889    0.0081364    0.0044963    0.0          0.0223111    0.0
ROW  9    0.0          0.0000942    0.0          0.0          0.0          0.0005118
ROW 10    0.0          0.0062929    0.0          0.0          0.0053317    0.2218103
ROW 11    0.0          0.0000321    0.0          0.0          0.0          0.0161653
ROW 12    0.0          0.0013842    0.0020231    0.0          0.0001239    0.0007438
ROW 13    0.0          0.0016749    0.0          0.0          0.0000012    0.0002047
ROW 14    0.0          0.0002716    0.0          0.0          0.0005246    0.0425865
ROW 15    0.0001360    0.0083254    0.0047865    0.0          0.0009705    0.0874385
ROW 16    0.0001280    0.0022516    0.0134762    0.0          0.0004192    0.0011600
ROW 17    0.0000160    0.0025915    0.0004332    0.0          0.0008882    0.0035551
ROW 18    0.0048650    0.0077787    0.0034910    0.0          0.0001123    0.0013647
ROW 19    0.0001280    0.0023684    0.0018486    0.0          0.0          0.0
ROW 20    0.0000080    0.0002321    0.0000421    0.0          0.0000151    0.0028455
ROW 21    0.0004161    0.0025185    0.0          0.0          0.0002652    0.0005391
ROW 22    0.0004401    0.0000792    0.0          0.0          0.0000440    0.0002934
ROW 23    0.0          0.0000212    0.0          0.0          0.0          0.0
ROW 24    0.0          0.0000416    0.0          0.0          0.0          0.0
ROW 25    0.0          0.0001003    0.0          0.0          0.0          0.0
ROW 26    0.0028326    0.0022701    0.0          0.0          0.0004922    0.0009144
ROW 27    0.0001680    0.0025977    0.0001746    0.0          0.0000359    0.0007506
ROW 28    0.0002721    0.0019097    0.0000736    0.0          0.0000359    0.0068783
ROW 29    0.0          0.0023547    0.0          0.0          0.0004354    0.0
ROW 30    0.0000160    0.0008416    0.0003680    0.0          0.0          0.0
ROW 31    0.0          0.0006580    0.0          0.0          0.0          0.0023269
ROW 32    0.0001440    0.0012449    0.0008517    0.0          0.0000058    0.0289938
ROW 33    0.0010722    0.0041873    0.0088811    0.0          0.0151381    0.2994363
ROW 34    0.0105782    0.1273597    0.1348231    0.0          0.0061342    0.1188616
ROW 35    0.0002721    0.0010013    0.0052765    0.0          0.0000046    0.0041147
ROW 36    0.0000160    0.0150497    0.0032261    0.0          0.0067075    0.0
ROW 37    0.3569863    0.0025499    0.0007928    0.0          0.0012739    0.0
ROW 38    0.0044329    0.0162250    0.0096529    0.0          0.0019536    0.0406213
ROW 39    0.0020004    0.0165696    0.2022780    0.0          0.0009276    0.0010167
ROW 40    0.0027926    0.0003044    0.0028097    0.0          0.0033074    0.1043680
ROW 41    0.0170996    0.0144081    0.0151229    0.0          0.0002223    0.0
ROW 42    0.0013363    0.0189940    0.0188242    0.0          0.0018622    0.0
```

D11

```
                 THE LEONTIEF INVERSE MATRIX OF THE INPUT/OUTPUT TABLE ( 42 SECTORS )

DETERMINANT=0.0012276925
            COL  1     COL  2     COL  3     COL  4     COL  5     COL  6     COL  7     COL  8     COL  9
ROW  1   1.5044756  0.0083713  0.0059906  0.0076513  0.0086419  0.0067015  0.0060722  0.0252139  0.0112770
ROW  2   0.0007345  1.0738344  0.0150318  0.0021121  0.0005819  0.0025293  0.0029827  0.0056614  0.0054838
ROW  3   0.0007447  0.0406267  1.1829691  0.0025958  0.0006685  0.0020880  0.0022526  0.0067590  0.0121006
ROW  4   0.0017042  0.0081650  0.0046175  1.2253637  0.0010188  0.0054629  0.0038142  0.0046237  0.0039565
ROW  5   0.0199930  0.0121228  0.0106211  0.0114803  1.0335855  0.0211999  0.0196298  0.0181908  0.0076194
ROW  6   0.0028480  0.0006251  0.0009801  0.0012816  0.0004306  1.0111170  0.0169745  0.0148954  0.0013408
ROW  7   0.0019132  0.0005629  0.0020400  0.0007828  0.0002795  0.0012801  1.0693502  0.0012303  0.0007501
ROW  8   0.0300775  0.0136298  0.0093633  0.0081456  0.0131649  0.0097217  0.0096666  1.0118361  0.0106925
ROW  9   0.0004494  0.0006007  0.0003812  0.0006578  0.0005377  0.0004459  0.0003991  0.0010066  1.0314569
ROW 10   0.1258757  0.0049675  0.0050108  0.0050696  0.0045486  0.0056718  0.0063491  0.0089489  0.0118704
ROW 11   0.0001632  0.0002013  0.0001932  0.0002134  0.0002203  0.0002431  0.0002765  0.0002958  0.0006780
ROW 12   0.0105866  0.0032771  0.0055348  0.0056044  0.0038056  0.0063580  0.0038106  0.0069759  0.0122457
ROW 13   0.0087251  0.0116229  0.0043449  0.0154670  0.0037002  0.0048789  0.0037355  0.0767707  0.0107600
ROW 14   0.0008705  0.0008535  0.0007533  0.0009043  0.0009132  0.0009509  0.0009342  0.0084283  0.0043829
ROW 15   0.0220194  0.0137504  0.0125054  0.0162194  0.0180575  0.0304192  0.0193404  0.0324601  0.0288629
ROW 16   0.0022061  0.0013887  0.0016070  0.0016255  0.0012825  0.0019549  0.0012334  0.0026589  0.0042943
ROW 17   0.0569692  0.0276031  0.0552313  0.0392294  0.0134146  0.0340308  0.0536638  0.0520707  0.0327976
ROW 18   0.0364245  0.0211718  0.0149342  0.0203316  0.0105010  0.0371648  0.0194659  0.0318599  0.0120020
ROW 19   0.0079898  0.0036557  0.0056759  0.0129469  0.0053227  0.0235299  0.0080865  0.0119609  0.0342861
ROW 20   0.0004072  0.0001981  0.0001820  0.0002647  0.0002117  0.0003107  0.0002122  0.0004302  0.0007956
ROW 21   0.0070416  0.0046322  0.0102453  0.0071311  0.0032348  0.0777666  0.0054265  0.0878886  0.0154592
ROW 22   0.0096064  0.0353789  0.0644230  0.0332212  0.0088774  0.0355744  0.0362080  0.0914516  0.0852984
ROW 23   0.0013008  0.0019402  0.0027596  0.0043599  0.0012484  0.0025022  0.0024927  0.0155797  0.0246626
ROW 24   0.0017623  0.0021781  0.0026665  0.0040981  0.0015353  0.0030334  0.0026739  0.0110019  0.0373659
ROW 25   0.0025341  0.0053378  0.0099489  0.0132567  0.0029012  0.0052027  0.0071203  0.0293244  0.0548241
ROW 26   0.0161414  0.0106710  0.0109119  0.0258527  0.0123561  0.0130378  0.0109666  0.1277483  0.0583279
ROW 27   0.0138565  0.0386597  0.0411521  0.0782850  0.0225795  0.0899910  0.0505215  0.0402830  0.1656926
ROW 28   0.0055938  0.0087203  0.0102392  0.0122211  0.0092167  0.0106030  0.0111588  0.0399607  0.1156542
ROW 29   0.0056236  0.0044029  0.0039457  0.0072367  0.0050045  0.0094971  0.0061187  0.0053223  0.0165225
ROW 30   0.0025892  0.0061959  0.0020551  0.0081806  0.0018622  0.0025507  0.0028916  0.0036265  0.2653965
ROW 31   0.0015779  0.0017166  0.0015772  0.0014766  0.0017222  0.0016956  0.0013690  0.0060491  0.0333077
ROW 32   0.0018834  0.0015978  0.0013052  0.0030129  0.0018303  0.0020862  0.0016092  0.0045870  0.0064593
ROW 33   0.0450953  0.1287200  0.0562844  0.0251693  0.0380905  0.0382642  0.0839990  0.0662074  0.0472252
ROW 34   0.1511621  0.1256626  0.0764168  0.0690820  0.2021729  0.0819654  0.0583800  0.1158310  0.0808800
ROW 35   0.0055629  0.0015820  0.0015807  0.0018958  0.0015677  0.0017892  0.0015870  0.0023001  0.0025415
ROW 36   0.0092303  0.0205304  0.0225635  0.0337646  0.0081753  0.0291223  0.0279521  0.0120068  0.0129247
ROW 37   0.0038912  0.0046768  0.0137255  0.0038237  0.0042537  0.0085313  0.0373156  0.0070573  0.0063227
ROW 38   0.0715984  0.0389340  0.0446320  0.0569393  0.0259726  0.0814304  0.0433877  0.1233608  0.0737397
ROW 39   0.0287046  0.0179324  0.0246478  0.0219854  0.0215468  0.0229149  0.0157917  0.0250815  0.0211921
ROW 40   0.0464898  0.3412825  0.2058599  0.0160336  0.0925642  0.0767699  0.1118456  0.0346334  0.0423067
ROW 41   0.0078832  0.0107569  0.0089575  0.0099369  0.0076188  0.0106914  0.0103176  0.0093855  0.0086183
ROW 42   0.0077860  0.0098421  0.0094748  0.0104448  0.0107470  0.0118742  0.0136514  0.0143888  0.0336410
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D12

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             COL 10     COL 11     COL 12     COL 13     COL 14     COL 15     COL 16     COL 17     COL 18
ROW  1     0.5678055  0.3735555  0.1224919  0.2410139  0.0426248  0.0291225  0.0165404  0.0284836  0.0095524
ROW  2     0.0012012  0.0005210  0.0008790  0.0009759  0.0054904  0.0010015  0.0006236  0.0048957  0.0013018
ROW  3     0.0010727  0.0006638  0.0010536  0.0009116  0.0028374  0.0010899  0.0008421  0.0054359  0.0010204
ROW  4     0.0030720  0.0017312  0.0034480  0.0019852  0.0050096  0.0117860  0.0033282  0.0093752  0.0025527
ROW  5     0.0145968  0.0080619  0.0091070  0.0134804  0.0086112  0.0158130  0.0069672  0.0347586  0.5740113
ROW  6     0.0021423  0.0010433  0.0009409  0.0012218  0.0022629  0.0035623  0.0011256  0.0032484  0.0043219
ROW  7     0.0013139  0.0012373  0.0026521  0.0010415  0.0012883  0.0032330  0.0011640  0.0234345  0.0012074
ROW  8     0.0245993  0.0134555  0.0113538  0.0145099  0.0108434  0.0153606  0.0168315  0.0157274  0.0159502
ROW  9     0.0005081  0.0003217  0.0003351  0.0004008  0.0005386  0.0005023  0.0011056  0.0005684  0.0005239
ROW 10     1.2583876  0.0440034  0.0207081  0.0257287  0.0172709  0.0177633  0.0144462  0.0392487  0.0070663
ROW 11     0.0002991  1.2359066  0.0003440  0.0003000  0.0003907  0.0003342  0.0007150  0.0004684  0.0002327
ROW 12     0.0123989  0.0056276  1.7276945  0.0089355  0.1005805  0.0251526  0.0106139  0.0119092  0.0045483
ROW 13     0.0106423  0.0094225  0.0062111  1.3711281  0.1524943  0.0993707  0.0234353  0.0117136  0.0048168
ROW 14     0.0012003  0.0006501  0.0022537  0.0044672  1.0337019  0.0015036  0.0025283  0.0015488  0.0009781
ROW 15     0.0531135  0.0570177  0.0433977  0.0326338  0.0530885  1.4142389  0.3052018  0.0781650  0.0268452
ROW 16     0.0048173  0.0043915  0.0038274  0.0061027  0.0033572  0.0146730  1.1347790  0.0061029  0.0017449
ROW 17     0.0405034  0.0544195  0.1430452  0.0469749  0.0598559  0.0815269  0.0436987  1.3715668  0.0620990
ROW 18     0.0252257  0.0140859  0.0151457  0.0241988  0.0139275  0.0253792  0.0114344  0.0567939  1.0905399
ROW 19     0.0078510  0.0057880  0.0142837  0.0107704  0.0375090  0.0223761  0.0077394  0.0175367  0.0054260
ROW 20     0.0003716  0.0003080  0.0052224  0.0004222  0.0031777  0.0005949  0.0005265  0.0004058  0.0002378
ROW 21     0.0171186  0.0037438  0.0066463  0.0104100  0.0340861  0.0118492  0.0051664  0.0202205  0.0071430
ROW 22     0.0183495  0.0062321  0.0084072  0.0143353  0.0926486  0.0130837  0.0082794  0.0233657  0.0147172
ROW 23     0.0021265  0.0009704  0.0014175  0.0014609  0.0043896  0.0016914  0.0013360  0.0039842  0.0018366
ROW 24     0.0040551  0.0033061  0.0020664  0.0036336  0.0188757  0.0040315  0.0035655  0.0074500  0.0027409
ROW 25     0.0034628  0.0019489  0.0033223  0.0028808  0.0083581  0.0035545  0.0029783  0.0114449  0.0035089
ROW 26     0.0464972  0.0118828  0.0117046  0.0229468  0.0840557  0.0261674  0.0131360  0.0375579  0.0324068
ROW 27     0.0115589  0.0066916  0.0115080  0.0124981  0.0242213  0.0159329  0.0125630  0.0225131  0.0173410
ROW 28     0.0063834  0.0034211  0.0041908  0.0060140  0.0105696  0.0067524  0.0063740  0.0077802  0.0081464
ROW 29     0.0047204  0.0029032  0.0025994  0.0029870  0.0050088  0.0026097  0.0034555  0.0039460  0.0044692
ROW 30     0.0028653  0.0015276  0.0018757  0.0035766  0.0034878  0.0024007  0.0038885  0.0026972  0.0027070
ROW 31     0.0018351  0.0011683  0.0018934  0.0012631  0.0040552  0.0018288  0.0048481  0.0042854  0.0018878
ROW 32     0.0028001  0.0028552  0.0206145  0.0035693  0.0115274  0.0032480  0.0059102  0.0039166  0.0023175
ROW 33     0.0786241  0.0356039  0.0502056  0.0835018  0.0566008  0.0767000  0.0499144  0.0715456  0.0905425
ROW 34     0.1643877  0.1184679  0.0944411  0.0887179  0.0925626  0.0840295  0.1595440  0.1546938  0.1726167
ROW 35     0.0038560  0.0030104  0.0029888  0.0027046  0.0024205  0.0023467  0.0024009  0.0024730  0.0023639
ROW 36     0.0116158  0.0056048  0.0153499  0.0121179  0.0141696  0.0186365  0.0115576  0.0189643  0.0126992
ROW 37     0.0062454  0.0027196  0.0048199  0.0035917  0.0060369  0.0121719  0.0040589  0.0172948  0.0210899
ROW 38     0.0832513  0.0446639  0.0884924  0.0784793  0.0931891  0.0761216  0.0565127  0.0630493  0.0364505
ROW 39     0.0264005  0.0153997  0.0241046  0.0211984  0.0197854  0.0210801  0.0251282  0.0274112  0.0266943
ROW 40     0.0714816  0.0240891  0.0520657  0.1042699  0.0364417  0.1116329  0.0354122  0.0522261  0.0936819
ROW 41     0.0104300  0.0082021  0.0103108  0.0089831  0.0090926  0.0114692  0.0161989  0.0142367  0.0119678
ROW 42     0.0140039  0.0071643  0.0167666  0.0147091  0.0191565  0.0157212  0.0353075  0.0230704  0.0113642
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D13

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              COL 19     COL 20     COL 21     COL 22     COL 23     COL 24     COL 25     COL 26     COL 27
ROW  1     0.0223425  0.0188650  0.0117189  0.0069106  0.0069436  0.0071526  0.0079437  0.0093724  0.0091822
ROW  2     0.0018206  0.0007525  0.0021264  0.0724767  0.0060835  0.0044265  0.0132201  0.0198867  0.0099960
ROW  3     0.0021206  0.0008882  0.0024613  0.0072330  0.2310888  0.0858477  0.1685048  0.0124152  0.0079037
ROW  4     0.0054482  0.0029621  0.0125403  0.0363077  0.0053929  0.0067497  0.0050512  0.0113559  0.0063035
ROW  5     0.0119825  0.0061575  0.0184544  0.0144572  0.0119682  0.0154365  0.0101900  0.0109919  0.0081723
ROW  6     0.0022313  0.0009407  0.0525192  0.0049137  0.0024824  0.0014815  0.0014108  0.0023325  0.0019377
ROW  7     0.0063147  0.0017779  0.0041398  0.0011315  0.0009755  0.0011487  0.0018321  0.0008780  0.0005899
ROW  8     0.0112317  0.0090769  0.0109037  0.0170422  0.0095584  0.0105084  0.0089249  0.0112885  0.0101789
ROW  9     0.0005979  0.0004377  0.0004157  0.0005840  0.0005228  0.0006529  0.0011897  0.0012852  0.0022987
ROW 10     0.0146502  0.0101055  0.0095061  0.0060425  0.0067267  0.0067172  0.0069181  0.0078740  0.0085746
ROW 11     0.0003914  0.0003425  0.0003487  0.0002380  0.0002843  0.0003045  0.0002737  0.0003791  0.0004608
ROW 12     0.1602871  0.0998992  0.0099237  0.0056051  0.0062757  0.0077217  0.0131164  0.0093818  0.0089806
ROW 13     0.0087157  0.0229461  0.0191134  0.0070194  0.0045347  0.0048972  0.0077463  0.0137383  0.0088206
ROW 14     0.0016471  0.0015841  0.0017976  0.0011199  0.0010876  0.0012509  0.0013483  0.0035144  0.0026108
ROW 15     0.0461808  0.0548501  0.0807824  0.0187835  0.0196051  0.0198830  0.0228430  0.0308720  0.0233383
ROW 16     0.0059069  0.0090156  0.0042670  0.0031578  0.0027647  0.0029242  0.0028258  0.0037845  0.0026879
ROW 17     0.2843417  0.0736083  0.0732394  0.0325852  0.0370188  0.0501109  0.0671172  0.0355194  0.0240458
ROW 18     0.0193402  0.0101131  0.0229300  0.0193431  0.0159998  0.0176709  0.0140047  0.0165541  0.0130641
ROW 19     1.0404663  0.0782984  0.0143141  0.0072952  0.0059920  0.0059872  0.0065505  0.0110457  0.0172239
ROW 20     0.0035615  1.3635445  0.0004610  0.0002454  0.0002576  0.0002655  0.0003142  0.0007111  0.0011168
ROW 21     0.0192489  0.0109548  1.1289406  0.0255263  0.0115076  0.0128257  0.0139338  0.0199716  0.0165672
ROW 22     0.0179386  0.0092054  0.0161931  1.2825737  0.0477176  0.0412353  0.0562724  0.3447180  0.1687656
ROW 23     0.0024810  0.0014145  0.0019882  0.0078258  1.4039736  0.0651284  0.1647955  0.0313340  0.0197381
ROW 24     0.0039157  0.0021095  0.0041799  0.0082618  0.0482170  1.4095707  0.0730444  0.0594881  0.0241722
ROW 25     0.0072796  0.0031438  0.0045692  0.0216064  0.1565312  0.1621291  1.1810884  0.0349929  0.0289604
ROW 26     0.0299066  0.0193668  0.0239958  0.0445675  0.0407012  0.0411164  0.0427868  1.0977659  0.0698200
ROW 27     0.0165031  0.0073412  0.0161076  0.0427287  0.0382534  0.0382958  0.0393138  0.0696896  1.1897917
ROW 28     0.0096333  0.0061564  0.0104448  0.0133558  0.0163322  0.0268053  0.0406493  0.0286980  0.0711396
ROW 29     0.0029216  0.0024434  0.0030260  0.0063829  0.0050835  0.0102499  0.0039569  0.0165357  0.0284347
ROW 30     0.0054794  0.0019849  0.0024800  0.0043449  0.0025497  0.0026423  0.0042903  0.0090868  0.0151104
ROW 31     0.0037044  0.0042721  0.0020480  0.0018449  0.0016900  0.0021979  0.0026876  0.0079658  0.0066631
ROW 32     0.0082145  0.0074706  0.0040274  0.0022379  0.0029182  0.0027863  0.0041769  0.0045906  0.0048545
ROW 33     0.0540078  0.0427476  0.0816974  0.0882140  0.0607491  0.0534888  0.0553068  0.0587681  0.0434669
ROW 34     0.1057435  0.1000878  0.0810924  0.0708023  0.0736406  0.0739221  0.0701323  0.0778509  0.0827346
ROW 35     0.0023431  0.0026144  0.0020833  0.0020442  0.0021774  0.0027077  0.0019299  0.0023112  0.0021178
ROW 36     0.0176117  0.0111067  0.0228921  0.0225186  0.0220322  0.0465884  0.0212299  0.0175351  0.0132300
ROW 37     0.0074336  0.0035549  0.0322899  0.0217308  0.0178954  0.0310906  0.0139658  0.0114080  0.0063565
ROW 38     0.0649900  0.0686827  0.0601478  0.0634040  0.0855585  0.0648118  0.0860575  0.0730790  0.0748756
ROW 39     0.0206498  0.0226032  0.0237265  0.0207494  0.0240640  0.0241994  0.0224541  0.0225024  0.0199640
ROW 40     0.0626673  0.0374972  0.0392945  0.0998092  0.2679546  0.1600282  0.2641056  0.0569022  0.0451855
ROW 41     0.0100804  0.0111618  0.0121352  0.0107982  0.0099087  0.0131533  0.0093544  0.0095501  0.0084348
ROW 42     0.0192578  0.0168159  0.0171637  0.0116729  0.0139411  0.0149775  0.0134038  0.0186893  0.0227793
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D14

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              COL 28     COL 29     COL 30     COL 31     COL 32     COL 33     COL 34     COL 35     COL 36
ROW  1     0.0118712  0.0103308  0.0096340  0.0139856  0.0239006  0.0112794  0.0374613  0.0173555  0.0072243
ROW  2     0.0069692  0.0114705  0.0078093  0.0036166  0.0041050  0.0008098  0.0009534  0.0006186  0.0007666
ROW  3     0.0128505  0.0054321  0.0073294  0.0095093  0.0105488  0.0010287  0.0011333  0.0007785  0.0010585
ROW  4     0.0048314  0.0081049  0.0053812  0.0037570  0.0041996  0.0022533  0.0023955  0.0016430  0.0385862
ROW  5     0.0075485  0.0086241  0.0075493  0.0066544  0.0090076  0.0291162  0.0096402  0.0072554  0.0223180
ROW  6     0.0020218  0.0022683  0.0014598  0.0016105  0.0016340  0.0011094  0.0014592  0.0009418  0.0009753
ROW  7     0.0010295  0.0009581  0.0006669  0.0010748  0.0017762  0.0003556  0.0005416  0.0008351  0.0002068
ROW  8     0.0110062  0.0148686  0.0094258  0.0093025  0.0137326  0.0472284  0.0611715  0.0422655  0.0453490
ROW  9     0.0143199  0.0015542  0.0493466  0.0230140  0.0009319  0.0011263  0.0022721  0.0007911  0.0002534
ROW 10     0.0116801  0.0071698  0.0071350  0.0139610  0.0138532  0.0087762  0.0092724  0.0207360  0.0043872
ROW 11     0.0006256  0.0003123  0.0003516  0.0005926  0.0006252  0.0002166  0.0003058  0.0005976  0.0001677
ROW 12     0.0124838  0.0368958  0.0106795  0.0240882  0.0600355  0.0062544  0.0125521  0.0124764  0.0020366
ROW 13     0.0118823  0.0071903  0.0194556  0.0085552  0.0405369  0.0066447  0.0116514  0.0075534  0.0052479
ROW 14     0.0142745  0.0021218  0.0074275  0.0057446  0.0031494  0.0011930  0.0023593  0.0059718  0.0008938
ROW 15     0.0427327  0.0287439  0.0188515  0.0509659  0.1094448  0.0162858  0.0827535  0.0401551  0.0093450
ROW 16     0.0033030  0.0028422  0.0026335  0.0025657  0.0085861  0.0037231  0.0039283  0.0017999  0.0011494
ROW 17     0.0465654  0.0413302  0.0297957  0.0516336  0.0866556  0.0152599  0.0213339  0.0439604  0.0090272
ROW 18     0.0117642  0.0132551  0.0118349  0.0105709  0.0147706  0.0543040  0.0148298  0.0098973  0.0245145
ROW 19     0.0247532  0.0424011  0.0154526  0.0169226  0.0419946  0.0099049  0.0050735  0.0029095  0.0024688
ROW 20     0.0011388  0.0010996  0.0006952  0.0025267  0.0196524  0.0004016  0.0006282  0.0005314  0.0001303
ROW 21     0.0293977  0.0289198  0.0169832  0.0230843  0.0163883  0.0062373  0.0096743  0.0062436  0.0066329
ROW 22     0.0978632  0.1979286  0.1312855  0.0540121  0.0603122  0.0123745  0.0138802  0.0082014  0.0123091
ROW 23     0.0246436  0.0135014  0.0131483  0.0187482  0.0210783  0.0019249  0.0021851  0.0014085  0.0016563
ROW 24     0.0273250  0.0199943  0.0343002  0.0228705  0.0230793  0.0024014  0.0024204  0.0016641  0.0023064
ROW 25     0.0602185  0.0164358  0.0295789  0.0395160  0.0510627  0.0046662  0.0045747  0.0029014  0.0026761
ROW 26     0.0740098  0.1141499  0.0762557  0.0531676  0.0498473  0.0135373  0.0159729  0.0113198  0.0176733
ROW 27     0.0565677  0.0679085  0.0980608  0.0561446  0.0222847  0.0126793  0.0198740  0.0067151  0.0075332
ROW 28     1.2116385  0.0488436  0.0734903  0.0834436  0.0258373  0.0110376  0.0149932  0.0067137  0.0047587
ROW 29     0.0104115  1.4262447  0.0206787  0.0190050  0.0052907  0.0068965  0.0166907  0.0032155  0.0017974
ROW 30     0.0135401  0.0059424  1.2076855  0.0237532  0.0059933  0.0187440  0.0052455  0.0028140  0.0016680
ROW 31     0.0172976  0.0092721  0.0207544  1.0693836  0.0035927  0.0025382  0.0074052  0.0167602  0.0008163
ROW 32     0.0051057  0.0038334  0.0046945  0.0074282  1.0645638  0.0031554  0.0072818  0.0038264  0.0013030
ROW 33     0.0486079  0.0593245  0.0420057  0.0416379  0.0503054  1.0827579  0.0248553  0.0262571  0.0509868
ROW 34     0.0999770  0.1030271  0.0652112  0.0968558  0.1091086  0.1228515  1.1472855  0.1635222  0.0501166
ROW 35     0.0024338  0.0025381  0.0022208  0.0021462  0.0024083  0.0017699  0.0023945  1.0143499  0.0013505
ROW 36     0.0141620  0.0142746  0.0133691  0.0109393  0.0142195  0.0074882  0.0104681  0.0172519  1.0687637
ROW 37     0.0064219  0.0079583  0.0065022  0.0050270  0.0055749  0.0031075  0.0042569  0.0096433  0.0478263
ROW 38     0.0789868  0.0755836  0.0641669  0.0802597  0.1037990  0.0473876  0.0456011  0.0383261  0.0298846
ROW 39     0.0180740  0.0195192  0.0159144  0.0180179  0.0244275  0.0348267  0.0386974  0.0241195  0.0135649
ROW 40     0.0462436  0.0799911  0.0380248  0.0558505  0.0969812  0.0461963  0.0176855  0.0132968  0.0110276
ROW 41     0.0108564  0.0106569  0.0078571  0.0086569  0.0107275  0.0325729  0.0269010  0.0092014  0.1524147
ROW 42     0.0309877  0.0153269  0.0173552  0.0293155  0.0235706  0.0105861  0.0139812  0.0291467  0.0075255
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           COL 37      COL 38      COL 39      COL 40       COL 41      COL 42      COL
ROW  1   0.0053363   0.0162305   0.0121505   0.0          0.0213432   0.1648893
ROW  2   0.0005657   0.0004118   0.0002912   0.0          0.0002380   0.0012300
ROW  3   0.0005597   0.0004600   0.0003483   0.0          0.0002256   0.0014076
ROW  4   0.0017805   0.0014736   0.0013299   0.0          0.0036311   0.0032523
ROW  5   0.3112421   0.0082723   0.0058625   0.0          0.0024369   0.0169084
ROW  6   0.0008016   0.0006817   0.0004804   0.0          0.0004493   0.0015946
ROW  7   0.0001655   0.0002678   0.0002193   0.0          0.0000986   0.0010171
ROW  8   0.0429335   0.0194045   0.0190405   0.0          0.0246993   0.0309133
ROW  9   0.0002654   0.0005706   0.0005057   0.0          0.0000735   0.0015405
ROW 10   0.0029575   0.0161312   0.0095735   0.0          0.0092151   0.2889343
ROW 11   0.0001353   0.0005065   0.0005637   0.0          0.0000581   0.0202470
ROW 12   0.0018788   0.0058003   0.0079926   0.0          0.0009269   0.0166590
ROW 13   0.0044356   0.0065064   0.0043403   0.0          0.0023983   0.0232192
ROW 14   0.0007896   0.0017274   0.0016880   0.0          0.0008866   0.0454040
ROW 15   0.0095150   0.0293644   0.0330240   0.0          0.0041787   0.1595598
ROW 16   0.0009407   0.0039113   0.0202463   0.0          0.0007442   0.0060204
ROW 17   0.0074405   0.0113272   0.0088747   0.0          0.0040851   0.0364149
ROW 18   0.0132548   0.0131940   0.0096522   0.0          0.0027291   0.0300317
ROW 19   0.0025522   0.0044131   0.0042070   0.0          0.0007614   0.0110452
ROW 20   0.0001354   0.0005820   0.0003717   0.0          0.0000638   0.0049730
ROW 21   0.0053988   0.0060291   0.0029604   0.0          0.0027684   0.0112361
ROW 22   0.0090410   0.0061440   0.0042250   0.0          0.0031686   0.0185895
ROW 23   0.0011864   0.0009020   0.0006665   0.0          0.0004801   0.0026250
ROW 24   0.0012510   0.0011526   0.0008062   0.0          0.0004413   0.0042418
ROW 25   0.0023201   0.0017821   0.0013981   0.0          0.0009217   0.0056629
ROW 26   0.0140719   0.0086291   0.0053038   0.0          0.0045794   0.0263813
ROW 27   0.0095424   0.0078348   0.0050987   0.0          0.0019226   0.0141588
ROW 28   0.0053351   0.0060056   0.0038771   0.0          0.0014779   0.0174380
ROW 29   0.0021920   0.0061928   0.0033364   0.0          0.0011191   0.0062742
ROW 30   0.0009695   0.0023090   0.0020476   0.0          0.0005144   0.0079004
ROW 31   0.0009673   0.0021095   0.0017204   0.0          0.0002931   0.0053546
ROW 32   0.0012399   0.0033114   0.0035271   0.0          0.0003533   0.0344236
ROW 33   0.0185812   0.0203835   0.0282086   0.0          0.0204232   0.3585163
ROW 34   0.0878640   0.1656057   0.2099456   0.0          0.0162152   0.2379844
ROW 35   0.0011100   0.0017799   0.0074163   0.0          0.0002292   0.0064732
ROW 36   0.0037179   0.0190590   0.0074697   0.0          0.0080133   0.0100850
ROW 37   1.5571680   0.0061704   0.0031252   0.0          0.0027026   0.0048984
ROW 38   0.0214603   1.0300436   0.0263918   0.0          0.0079115   0.0969115
ROW 39   0.0126469   0.0286646   1.2627697   0.0          0.0033399   0.0279144
ROW 40   0.0351312   0.0103655   0.0133718   1.0000000    0.0066084   0.1528694
ROW 41   0.0302036   0.0221482   0.0258499   0.0          1.0024595   0.0184115
ROW 42   0.0066253   0.0230862   0.0279068   0.0          0.0028643   1.0126419
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## Distribution by Average Consumption by Sector

| | PERCENT | SECTOR DEFINITION |
|---|---|---|
| SECTOR- 1 | 0.011847 | AGRICULTURAL |
| SECTOR- 2 | 0.0 | IRON MINES |
| SECTOR- 3 | 0.0 | NON-FERROUS MINES |
| SECTOR- 4 | 0.000704 | COAL MINES |
| SECTOR- 5 | 0.0 | CRUDE PETRO.-NATURAL GAS |
| SECTOR- 6 | 0.000052 | STONE AND CLAY MINING |
| SECTOR- 7 | 0.000004 | CHEMICAL MINING |
| SECTOR- 8 | 0.0 | CONSTRUCTION |
| SECTOR- 9 | 0.000595 | ORDINANCE (SIC 19) |
| SECTOR-10 | 0.154956 | FOOD PRODUCTS (SIC 20) |
| SECTOR-11 | 0.014550 | TOBACCO PRODUCTS(SIC 21) |
| SECTOR-12 | 0.047980 | TEXTILE PRODUCTS (SIC 22,23) |
| SECTOR-13 | 0.000510 | LUMBER-WOOD PRODUCTS(SIC 24) |
| SECTOR-14 | 0.008813 | FURNITURE-FIXTURES (SIC 25) |
| SECTOR-15 | 0.002897 | PAPER PRODUCTS (SIC 26) |
| SECTOR-16 | 0.008361 | PRINTING-PUBLISHING (SIC 27) |
| SECTOR-17 | 0.014029 | CHEMICAL PRODUCTS (SIC 28) |
| SECTOR-18 | 0.022549 | PETROLEUM REFINING (SIC 29) |
| SECTOR-19 | 0.004912 | RUBBER-PLASTIC PROD.(SIC 30) |
| SECTOR-20 | 0.008947 | LEATHER PRODUCTS (SIC 31) |
| SECTOR-21 | 0.001244 | STONE,CLAY AND GLASS(SIC 32) |
| SECTOR-22 | 0.000059 | IRON AND STEEL MANU.(SIC 33) |
| SECTOR-23 | 0.0 | COPPER MANUFACTURING(SIC 33) |
| SECTOR-24 | 0.000020 | ALUMINUM MANUFACTURE(SIC 33) |
| SECTOR-25 | 0.000017 | OTHER NON-FERROUS MET(SIC33) |
| SECTOR-26 | 0.002557 | FABRICATED METAL PROD(SIC34) |
| SECTOR-27 | 0.001701 | MACHINERY,EX.ELECTRIC(SIC35) |
| SECTOR-28 | 0.016406 | ELECTRICAL MACHINERY(SIC 36) |
| SECTOR-29 | 0.037152 | MOTOR VEHICLES (SIC 371) |
| SECTOR-30 | 0.003175 | OTHER TRANSPORTATION(SIC 37) |
| SECTOR-31 | 0.003129 | INSTRUMENTS (SIC 38) |
| SECTOR-32 | 0.009590 | MISCELLANEUS MANUFAC.(SIC39) |
| SECTOR-33 | 0.026651 | TRANSPORTATION-WAREHOUSING |
| SECTOR-34 | 0.225173 | OTHER SERVICES |
| SECTOR-35 | 0.080286 | MEDICAL, EDUC. & NON-PROFIT |
| SECTOR-36 | 0.015634 | ELECTRIC UTILITIES (SIC 4911 |
| SECTOR-37 | 0.009600 | GAS UTILITIES (SIC 492) |
| SECTOR-38 | 0.199479 | WHOLESALE & RETAIL TRADE |
| SECTOR-39 | 0.049824 | FINANCE & SERVICES |
| SECTOR-40 | 0.013115 | IMPORT OF GOODS AND SERVICES |
| SECTOR-41 | 0.003497 | GOVERNMENT ENTERPRISES |
| SECTOR-42 | 0.000015 | MISCELLANEOUS BUSINESS |

## 3. Interregional Feedback Regional Market Shares by AQCR by Industry

As described in Appendix C, changes in the final demand of the nation (by sectors) will have a chain reaction on the national economy.

The next question is how will such structural changes affect each AQCR. It is argued that the regional share of the national market by each industry is stable.* Therefore, any changes of production at national level will have a proportional effect on each region of its market shares.

By definition, regional market share by industry by AQCR is:

$$b_{ij} = \frac{X_{ij}}{X_j^N}$$

$b_{ij}$ is the regional market share of jth industry product from ith AQCR

$X_{ij}$ is the output (value-added) of jth industry in ith AQCR

$X_j^N$ is the output (value-added) of jth industry in the nation

A regional market share matrix

$$B = [b_{ij}]$$

has been estimated for 100 AQCR's and two-digit manufacturing industries (SIC 20 to SIC39).

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* Sometimes this is called "locational quotient" of the industry.

CONSAD has developed a computer program, namely, Program FBE (Feedback Effects), which uses B matrix to distribute the change obtained from the I-O model.

## $B = (b_{ij})$ REGIONAL MARKET SHARE COEFFICIENT MATRIX

| AQCR | SIC 20 | SIC 22 | SIC 23 | SIC 24 | SIC 25 | SIC 26 | SIC 27 | SIC 28 | SIC 29 | SIC 30 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .0624 | .0359 | .1790 | .0099 | .0478 | .0440 | .2470 | .1077 | .0109 | .0323 |
| 2 | .0832 | .0 | .0161 | .0091 | .0468 | .0504 | .1135 | .1244 | .0654 | .0631 |
| 3 | .0464 | .0062 | .0265 | .0134 | .0624 | .0283 | .0442 | .0606 | .1304 | .0612 |
| 4 | .0387 | .0259 | .0299 | .0051 | .0166 | .0464 | .0469 | .1054 | .1396 | .0415 |
| 5 | .0158 | .0020 | .0070 | .0040 | .0070 | .0091 | .0205 | .0440 | .0341 | .0286 |
| 6 | .0356 | .0006 | .0042 | .0035 | .0131 | .0160 | .0233 | .0288 | .1437 | .0069 |
| 7 | .0201 | .0053 | .0117 | .0035 | .0080 | .0171 | .0304 | .0177 | .0100 | .0420 |
| 8 | .0131 | .0004 | .0009 | .0015 | .0026 | .0053 | .0089 | .0143 | .0055 | .0050 |
| 9 | .0237 | .0018 | .0061 | .0022 | .0079 | .0113 | .0157 | .0510 | .0883 | .0067 |
| 10 | .0060 | .0 | .0001 | .0008 | .0011 | .0022 | .0211 | .0022 | .0042 | .0004 |
| 11 | .0091 | .0028 | .0076 | .0012 | .0115 | .0094 | .0195 | .0299 | .0251 | .0137 |
| 12 | .0180 | .0012 | .0090 | .0020 | .0066 | .0113 | .0104 | .0328 | .0078 | .0092 |
| 13 | .0043 | .0019 | .0006 | .0008 | .0014 | .0029 | .0035 | .0019 | .0 | .0003 |
| 14 | .0161 | .0008 | .0026 | .0054 | .0041 | .0102 | .0187 | .0195 | .0251 | .0 |
| 15 | .0133 | .0003 | .0008 | .0034 | .0037 | .0074 | .0057 | .0811 | .2215 | .0042 |
| 16 | .0121 | .0016 | .0011 | .0014 | .0043 | .0143 | .0085 | .0294 | .0135 | .0126 |
| 17 | .0189 | .0012 | .0014 | .0014 | .0031 | .0069 | .0109 | .0075 | .0032 | .0033 |
| 18 | .0205 | .0009 | .0026 | .0015 | .0097 | .0120 | .0149 | .0486 | .0 | .0122 |
| 19 | .0153 | .0004 | .0012 | .0051 | .0073 | .0027 | .0060 | .0308 | .0032 | .0009 |
| 20 | .0104 | .0004 | .0061 | .0012 | .0057 | .0059 | .0097 | .0117 | .0035 | .0030 |
| 21 | .0083 | .0002 | .0013 | .0125 | .0021 | .0133 | .0052 | .0023 | .0032 | .0008 |
| 22 | .0130 | .0001 | .0040 | .0011 | .0044 | .0076 | .0136 | .0205 | .0328 | .0026 |
| 23 | .0034 | .0 | .0008 | .0006 | .0015 | .0001 | .0036 | .0013 | .0016 | .0004 |
| 24 | .0093 | .0033 | .0062 | .0012 | .0063 | .0090 | .0076 | .0090 | .0011 | .0014 |
| 25 | .0089 | .0 | .0004 | .0027 | .0021 | .0050 | .0069 | .0270 | .0064 | .0114 |
| 26 | .0046 | .0005 | .0027 | .0009 | .0056 | .0020 | .0049 | .0015 | .0005 | .0015 |
| 27 | .0108 | .0001 | .0006 | .0007 | .0024 | .0017 | .0066 | .0053 | .0080 | .0148 |
| 28 | .0093 | .0 | .0021 | .0008 | .0007 | .0036 | .0031 | .0039 | .0141 | .0005 |
| 29 | .0079 | .0023 | .0020 | .0119 | .0049 | .0184 | .0039 | .0048 | .0048 | .0014 |
| 30 | .0037 | .0152 | .0018 | .0 | .0 | .0038 | .0040 | .0046 | .0 | .0205 |
| 31 | .0038 | .0 | .0008 | .0010 | .0015 | .0009 | .0033 | .0017 | .0006 | .0005 |
| 32 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 33 | .0062 | .0 | .0003 | .0006 | .0031 | .0030 | .0062 | .0065 | .0 | .0049 |
| 34 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 35 | .0044 | .0009 | .0004 | .0012 | .0024 | .0089 | .0120 | .0064 | .0010 | .0271 |
| 36 | .0037 | .0008 | .0005 | .0008 | .0023 | .0012 | .0024 | .0028 | .0016 | .0005 |
| 37 | .0040 | .0 | .0002 | .0010 | .0024 | .0056 | .0022 | .0049 | .0388 | .0024 |
| 38 | .0009 | .0 | .0002 | .0 | .0 | .0007 | .0 | .0 | .0 | .0 |
| 39 | .0024 | .0074 | .0003 | .0009 | .0007 | .0022 | .0009 | .0147 | .0 | .0013 |
| 40 | .0068 | .0008 | .0008 | .0053 | .0042 | .0102 | .0031 | .0174 | .0036 | .0090 |
| 41 | .0033 | .0 | .0003 | .0 | .0014 | .0 | .0022 | .0011 | .0 | .0 |

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42   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
43   .0112    .0       .0003    .0       .0022    .0009    .0027    .0020    .0       .0
44   .0059    .0       .0       .0       .0       .0       .0017    .0       .0       .0
45   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
46   .0035    .0044    .0011    .0       .0016    .0019    .0025    .0037    .0       .0
47   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
48   .0010    .0       .0       .0007    .0       .0       .0008    .0       .0       .0
49   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
50   .0016    .0       .0029    .0       .0       .0       .0008    .0       .0       .0
51   .0       .0       .0       .0       .0       .0       .0007    .0026    .0       .0
52   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
53   .0005    .0       .0       .0       .0       .0       .0005    .0       .0       .0
54   .0009    .0       .0       .0       .0       .0       .0       .0       .0152    .0
55   .0036    .0       .0       .0       .0       .0       .0       .0       .0       .0
56   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
57   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
58   .0005    .0       .0       .0       .0       .0       .0       .0       .0       .0
59   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
60   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
61   .0043    .0060    .0073    .0002    .0009    .0046    .0035    .0051    .0019    .0011
62   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
63   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
64   .0029    .0       .0004    .0013    .0010    .0008    .0014    .0003    .0       .0040
65   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
66   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
67   .0016    .0092    .0016    .0012    .0143    .0023    .0012    .0060    .0       .0019
68   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
69   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
70   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
71   .0001    .0014    .0017    .0010    .0031    .0009    .0065    .0127    .0016    .0033
72   .0098    .0       .0001    .0007    .0006    .0014    .0022    .0016    .0       .0
73   .0028    .0       .0014    .0017    .0028    .0056    .0035    .0161    .0       .0005
74   .0107    .0007    .0045    .0006    .0027    .0038    .0068    .0053    .0       .0057
75   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
76   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
77   .0053    .0005    .0003    .0006    .0006    .0060    .0039    .0116    .0       .0020
78   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
79   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
80   .0015    .0       .0002    .0003    .0043    .0005    .0013    .0009    .0       .0031
81   .0042    .0041    .0027    .0007    .0006    .0105    .0051    .0102    .0010    .0009
82   .0008    .0001    .0002    .0005    .0022    .0007    .0015    .0008    .0       .0045
83   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
84   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
85   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
86   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
87   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
88   .0       .0       .0       .0       .0       .0       .0       .0       .0       .0
```

|  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 | .0026 | .0016 | .0023 | .0005 | .0007 | .0007 | .0019 | .0032 | .0 | .0003 |
| 91 | .0013 | .0 | .0 | .0022 | .0 | .0142 | .0008 | .0071 | .0 | .0 |
| 92 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 93 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 94 | .0029 | .0049 | .0017 | .0004 | .0015 | .0025 | .0012 | .0026 | .0 | .0016 |
| 95 | .0028 | .0001 | .0000 | .0002 | .0021 | .0005 | .0010 | .0015 | .0 | .0005 |
| 96 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 97 | .0013 | .0 | .0005 | .0 | .0 | .0 | .0011 | .0 | .0 | .0 |
| 98 | .0019 | .0010 | .0006 | .0006 | .0020 | .0022 | .0010 | .0026 | .0 | .0005 |
| 99 | .0030 | .0 | .0002 | .0001 | .0005 | .0004 | .0016 | .0015 | .0351 | .0004 |
| 100 | .0035 | .0029 | .0018 | .0007 | .0087 | .0066 | .0030 | .0004 | .0027 | .0014 |

| AQCR | SIC 31 | SIC 32 | SIC 33 | SIC 34 | SIC 35 | SIC 36 | SIC 37 | SIC 38 | SIC 39 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | .0616 | .0231 | .0170 | .0466 | .0283 | .0634 | .0466 | .0936 | .1678 |
| 2 | .0182 | .0403 | .0655 | .0952 | .0828 | .0927 | .0309 | .1268 | .0678 |
| 3 | .0094 | .0430 | .0251 | .0553 | .0434 | .0638 | .1118 | .0643 | .0482 |
| 4 | .0085 | .0268 | .0430 | .0411 | .0349 | .0390 | .0231 | .0510 | .0164 |
| 5 | .0004 | .0263 | .0671 | .0468 | .0732 | .0049 | .1788 | .0085 | .0104 |
| 6 | .0031 | .0162 | .0140 | .0226 | .0099 | .0127 | .0112 | .0061 | .0096 |
| 7 | .0418 | .0060 | .0036 | .0230 | .0202 | .0334 | .0140 | .0677 | .0134 |
| 8 | .0003 | .0306 | .1185 | .0264 | .0148 | .0148 | .0051 | .0123 | .0059 |
| 9 | .0139 | .0217 | .0244 | .0180 | .0129 | .0085 | .0474 | .0119 | .0087 |
| 10 | .0 | .0055 | .0 | .0021 | .0008 | .0057 | .0021 | .0028 | .0010 |
| 11 | .0002 | .0095 | .0458 | .0329 | .0376 | .0195 | .0393 | .0148 | .0102 |
| 12 | .0042 | .0135 | .0448 | .0104 | .0082 | .0174 | .0208 | .0019 | .0037 |
| 13 | .0002 | .0022 | .0008 | .0043 | .0139 | .0028 | .0363 | .0048 | .0022 |
| 14 | .0011 | .0201 | .0022 | .0057 | .0269 | .0129 | .0076 | .0335 | .0087 |
| 15 | .0002 | .0118 | .0118 | .0123 | .0144 | .0018 | .0012 | .0019 | .0019 |
| 16 | .0 | .0149 | .0378 | .0058 | .0096 | .0089 | .0267 | .0087 | .0048 |
| 17 | .0160 | .0051 | .0163 | .0152 | .0241 | .0290 | .0109 | .0123 | .0057 |
| 18 | .0034 | .0060 | .0043 | .0124 | .0121 | .0088 | .0252 | .0048 | .0102 |
| 19 | .0 | .0064 | .0023 | .0065 | .0082 | .0068 | .0036 | .0004 | .0018 |
| 20 | .0005 | .0081 | .0050 | .0056 | .0079 | .0148 | .0115 | .0028 | .0023 |
| 21 | .0005 | .0069 | .0022 | .0051 | .0041 | .0016 | .0636 | .0008 | .0020 |
| 22 | .0016 | .0093 | .0073 | .0073 | .0059 | .0060 | .0222 | .0022 | .0020 |
| 23 | .0002 | .0022 | .0001 | .0009 | .0021 | .0030 | .0091 | .0008 | .0013 |
| 24 | .0046 | .0072 | .0019 | .0039 | .0020 | .0019 | .0290 | .0004 | .0061 |
| 25 | .0002 | .0046 | .0040 | .0066 | .0100 | .0108 | .0234 | .0018 | .0035 |
| 26 | .0026 | .0040 | .0009 | .0051 | .0007 | .0008 | .0010 | .0010 | .0024 |
| 27 | .0059 | .0055 | .0010 | .0039 | .0033 | .0017 | .0143 | .0026 | .0029 |
| 28 | .0 | .0091 | .0036 | .0041 | .0007 | .0001 | .0063 | .0012 | .0012 |
| 29 | .0003 | .0045 | .0049 | .0046 | .0040 | .0034 | .0030 | .0035 | .0023 |
| 30 | .0039 | .0043 | .0095 | .0082 | .0065 | .0043 | .0014 | .0149 | .0553 |
| 31 | .0002 | .0043 | .0024 | .0018 | .0034 | .0055 | .0048 | .0059 | .0007 |
| 32 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 33 | .0041 | .0091 | .0023 | .0123 | .0069 | .0106 | .0100 | .0060 | .0032 |
| 34 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 35 | .0 | .0052 | .0028 | .0037 | .0252 | .0167 | .0064 | .0006 | .0019 |
| 36 | .0 | .0058 | .0428 | .0080 | .0012 | .0006 | .0050 | .0004 | .0009 |
| 37 | .0002 | .0276 | .0053 | .0063 | .0056 | .0034 | .0139 | .0020 | .0017 |
| 38 | .0 | .0030 | .0112 | .0032 | .0 | .0 | .0 | .0 | .0 |
| 39 | .0016 | .0047 | .0014 | .0054 | .0013 | .0005 | .0005 | .0 | .0005 |
| 40 | .0 | .0020 | .0005 | .0018 | .0029 | .0017 | .0008 | .0 | .0024 |
| 41 | .0 | .0024 | .0 | .0019 | .0020 | .0008 | .0 | .0 | .0009 |

```
42   .0      .0      .0      .0      .0      .0      .0      .0      .0
43   .0      .0015   .0      .0014   .0025   .0      .0004   .0      .0031
44   .0      .0025   .0      .0      .0      .0      .0      .0      .0
45   .0      .0      .0      .0      .0      .0      .0      .0      .0
46   .0      .0013   .0010   .0017   .0013   .0005   .0      .0      .0
47   .0      .0      .0      .0      .0      .0      .0      .0      .0
48   .0      .0022   .0      .0      .0      .0      .0      .0      .0
49   .0      .0      .0      .0      .0      .0      .0      .0      .0
50   .0      .0011   .0      .0003   .0      .0      .0      .0      .0
51   .0      .0033   .0      .0      .0      .0      .0      .0      .0
52   .0      .0      .0      .0      .0      .0      .0      .0      .0
53   .0      .0      .0      .0      .0      .0      .0      .0      .0
54   .0      .0      .0      .0      .0      .0      .0      .0      .0
55   .0      .0      .0      .0      .0      .0      .0      .0      .0
56   .0      .0      .0      .0      .0      .0      .0      .0      .0
57   .0      .0      .0      .0      .0      .0      .0      .0      .0
58   .0      .0      .0      .0      .0      .0      .0      .0      .0
59   .0      .0      .0      .0      .0      .0      .0      .0      .0
60   .0      .0      .0      .0      .0      .0      .0      .0      .0
61   .0023   .0106   .0179   .0040   .0039   .0057   .0034   .0006   .0062
62   .0      .0      .0      .0      .0      .0      .0      .0      .0
63   .0      .0      .0      .0      .0      .0      .0      .0      .0
64   .0      .0022   .0080   .0022   .0167   .0001   .0003   .0      .0011
65   .0      .0      .0      .0      .0      .0      .0      .0      .0
66   .0      .0      .0      .0      .0      .0      .0      .0      .0
67   .0      .0015   .0001   .0011   .0005   .0011   .0005   .0004   .0005
68   .0      .0      .0      .0      .0      .0      .0      .0      .0
69   .0      .0      .0      .0      .0      .0      .0      .0      .0
70   .0      .0      .0      .0      .0      .0      .0      .0      .0
71   .0049   .0134   .0001   .0029   .0006   .0011   .0021   .0032   .0012
72   .0      .0007   .0044   .0015   .0155   .0001   .0001   .0004   .0004
73   .0002   .0020   .0019   .0017   .0005   .0      .0002   .0013   .0010
74   .0007   .0033   .0010   .0045   .0122   .0124   .0004   .2883   .0067
75   .0      .0      .0      .0      .0      .0      .0      .0      .0
76   .0      .0      .0      .0      .0      .0      .0      .0      .0
77   .0011   .0031   .0047   .0041   .0091   .0144   .0022   .0013   .0032
78   .0      .0      .0      .0      .0      .0      .0      .0      .0
79   .0      .0      .0      .0      .0      .0      .0      .0      .0
80   .0009   .0033   .0407   .0075   .0038   .0040   .0083   .0004   .0003
81   .0      .0126   .0034   .0016   .0052   .0047   .0021   .0013   .0025
82   .0151   .0005   .0004   .0007   .0080   .0078   .0016   .0126   .0002
83   .0      .0      .0      .0      .0      .0      .0      .0      .0
84   .0      .0      .0      .0      .0      .0      .0      .0      .0
85   .0      .0      .0      .0      .0      .0      .0      .0      .0
86   .0      .0      .0      .0      .0      .0      .0      .0      .0
87   .0      .0      .0      .0      .0      .0      .0      .0      .0
88   .0      .0      .0      .0      .0      .0      .0      .0      .0
```

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 89 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 90 | .0053 | .0037 | .0020 | .0051 | .0037 | .0060 | .0004 | .0087 | .0094 |
| 91 | .0 | .0017 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 92 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 93 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 94 | .0033 | .0015 | .0070 | .0021 | .0028 | .0030 | .0026 | .0036 | .0015 |
| 95 | .0 | .0025 | .0015 | .0109 | .0116 | .0002 | .0029 | .0138 | .0016 |
| 96 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 | .0 |
| 97 | .0 | .0 | .0005 | .0011 | .0050 | .0005 | .0006 | .0 | .0 |
| 98 | .0043 | .0006 | .0050 | .0018 | .0051 | .0047 | .0020 | .0009 | .0061 |
| 99 | .0 | .0007 | .0002 | .0026 | .0007 | .0 | .0183 | .0013 | .0005 |
| 100 | .0069 | .0025 | .0013 | .0032 | .0050 | .0014 | .0005 | .0032 | .0012 |

# APPENDIX E

# DATA USED IN THE MODEL

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## Appendix E

This appendix provides a listing of sources of data, and types of data specified by input card format of the model.

# LIST OF DATA

## Sources

Annual Survey of Manufacturers, 1954-1966
Census of Manufacturers, 1963, 1967
County-City Data Book, 1967, 1969
Individual Income Tax Returns, 1968
Current Population Reports
County Business Patterns, 1967, 1969
Employment and Earnings Statistics for States and Areas, 1968, 1969
Manpower Report of the President, 1969
Census of Government, 1962, 1967
Consumer Expenditures and Income, 1960-1961, for SMSA
Sales Management Magazine, 1956, 1969
Survey of Current Business (monthly publication)
Statistical Abstracts of the United States, 1967, 1968, 1969
Costs and Economic Impact of Air Pollution Control, Fiscal Years 1970-1974 (NAPCA, January, 1969)
Comprehensive Economic Cost Study of Air Pollution Control Costs for Selected Industries and Selected Regions (RTI, February, 1970)
The Fuel of Fifty Cities (Ernst and Ernst, November, 1968)
Manufacturer's Report of Air Pollution Control Equipment Sales, 1966, 1967, 1968 (Industrial Gas Cleaning Institute Co.)
Economic Projections for Air Quality Control Regions (OBE Department of Commerce, June, 1970)

## LIST OF THE 100 AIR QUALITY CONTROL REGIONS (AQCRs)

| Code | AQCR |
|---|---|
| 1 | New York, New York |
| 2 | Chicago, Illinois |
| 3 | Los Angeles, California |
| 4 | Philadelphia, Pa. |
| 5 | Detroit, Michigan |
| 6 | San Francisco, California |
| 7 | Boston, Massachusetts |
| 8 | Pittsburgh, Pa. |
| 9 | St. Louis, Missouri |
| 10 | Washington, D.C. |
| 11 | Cleveland, Ohio |
| 12 | Baltimore, Maryland |
| 13* | Hartford-New Haven, Connecticut |
| 14 | Minneapolis-St. Paul, Minnesota |
| 15 | Houston, Texas |
| 16 | Buffalo, New York |
| 17 | Milwaukee, Wisconsin |
| 18 | Cincinnati, Ohio |
| 19 | Louisville, Kentucky |
| 20 | Dallas, Texas |
| 21 | Seattle-Everett, Washington |
| 22 | Kansas City, Missouri |
| 23 | San Diego, California |
| 24 | Atlanta, Georgia |
| 25 | Indianapolis, Indiana |
| 26 | Miami, Florida |
| 27 | Denver, Colorado |
| 28 | New Orleans, Louisiana |
| 29 | Portland, Oregon |
| 30 | Providence-Pawtucket, Rhode Island |
| 31 | Phoenix, Arizona |
| 32 | Tampa, Florida |
| 33 | Columbus, Ohio |
| 34 | San Antonio, Texas |
| 35 | Dayton, Ohio |
| 36 | Birmingham, Alabama |
| 37 | Toledo, Ohio |

100 AQCRs (continued)

| Code | AQCR |
|---|---|
| 38 | Steubenville-Weirton, Ohio/Wheeling, West Virginia |
| 39 | Chattanooga, Tennessee |
| 40 | Memphis, Tennessee |
| 41 | Salt Lake City, Utah |
| 42 | Oklahoma City, Oklahoma |
| 43 | Omaha, Nebraska |
| 44 | Honolulu, Hawaii |
| 45 | Beaumont-Port Arthur-Orange, Texas |
| 46 | Charlotte, North Carolina |
| 47 | Portland, Maine |
| 48 | Albuquerque, New Mexico |
| 49 | Lawrence-Haverhill/Lowell, Massachusetts |
| 50 | El Paso, Texas |
| 51 | Las Vegas, Nevada |
| 52 | Fargo-Moorhead, North Dakota/Minnesota |
| 53 | Boise, Idaho |
| 54 | Billings, Montana |
| 55 | Sioux City, South Dakota |
| 56* | Cheyenne, Wyoming |
| 57* | Anchorage, Alaska |
| 58* | Burlington, Vermont |
| 59* | San Juan, Puerto Rico |
| 60* | Virgin Islands |
| 61 | Allentown-Bethlehem-Easton, Pa., New Jersey |
| 62* | Anderson-Muncie, Indiana |
| 63 | Bakersfield, California |
| 64 | Davenport-Rock Island-Moline, Iowa, Illinois |
| 65* | Flint, Michigan |
| 66 | Grand Rapids/Muskegon-Muskegon Hts., Michigan |
| 67 | Greensboro, North Carolina |
| 68 | Harrisburg, Pa. |
| 69 | Jacksonville, Florida |
| 70 | Knoxville, Tennessee |
| 71 | Nashville, Tennessee |
| 72 | Peoria, Illinois |
| 73 | Richmond, Virginia |
| 74 | Rochester, New York |
| 75 | Saginaw/Bay City, Michigan |

100 AQCRs (continued)

| Code | AQCR |
|---|---|
| 76 | Scranton/Wilkes Barre-Hazelton, Pa. |
| 77 | Syracuse, New York |
| 78 | Tulsa, Oklahoma |
| 79* | Worcester, Massachusetts |
| 80 | Youngstown-Warren, Ohio |
| 81 | Albany-Schenectady-Troy, New York |
| 82 | Binghamton, New York |
| 83 | Charleston, South Carolina |
| 84 | Charleston, West Virginia |
| 85 | Des Moines, Iowa |
| 86 | Fresno, California |
| 87 | Fort Wayne, Indiana |
| 88 | Jackson, Mississippi |
| 89 | Johnstown, Pa. |
| 90 | Lancaster, Pa. |
| 91 | Mobile, Alabama |
| 92 | Norfolk-Portsmouth/Newport News-Hampton, Va. |
| 93 | Raleigh/Durham, North Carolina |
| 94 | Reading, Pa. |
| 95 | Rockford, Illinois |
| 96 | Sacramento, California |
| 97 | South Bend, Indiana |
| 98 | Utica-Rome, New York |
| 99 | Wichita, Kansas |
| 100 | York, Pa. |

*Data not available for this AQCR.

## CARD TYPE IDENTIFICATION AND VARIABLE LIST

The general format for all cards is 7F10.0, I1, I2, I3, and 2I2. The first seven fields contain specific data depending upon the codes in columns 71 through 80. These codes are as follows:

| Column | Contains |
|---|---|
| 71 | 1 -- Indicates the card contains figures for fuel and electric energy consumption<br>Blank -- Anything else |
| 72-73 | Last two digits of year of the data |
| 74-76 | From 001 to 100 -- Indicates card contains data for a specific AQCR (Air Quality Control Region)<br>Blank -- Indicates card contains totals for the United States |
| 77-78 | 00 -- Indicates the card contains all industry totals<br>From 20 to 39 -- Indicates the card contains data for a particular industry (2-digit SIC)<br>40 -- Indicates card contains Air Quality Control costs<br>41 -- Indicates card contains Unemployment figures and Sulfur Maximum Restriction costs<br>42 -- Indicates card contains Local Government figures and Population figures |
| 79-80 | Number of cards within a specific AQCR or SIC and year for a particular set of data |

## DESCRIPTION OF CARD TYPES

| Card Type | Identifying Codes Col. | Contains | Data Sets Using This Card Type |
|---|---|---|---|
| 1 | 71 | Blank | 1963 General Statistics -- All Industries Total for AQCR's |
| | 77-78 | 00 | 1967 General Statistics -- All Industries Total for AQCR's 1954-1967 Time Series Data -- All Industries Total for AQCR's |
| 2 | 71 | Blank | 1963 General Statistics -- by SIC for AQCR's |
| | 77-78 | 20 to 39 | 1967 General Statistics -- by SIC for AQCR's 1954-1967 Time Series Data by SIC for AQCR's |
| 3 | 77&78<br>79&80 | 40<br>01 | 1971-1975 Air Quality Control Costs for AQCR's (Card 1) |
| 4 | 77&78<br>79&80 | 40<br>02 | 1971-1975 Air Quality Control Costs for AQCR's (Card 2) |
| 5 | 77&78 | 41 | 1967 Unemployment & Work Force figures for AQCR's |
| 6 | 77&78 | 42 | 1967 AQCR's Local Government and Private Income |
| 7 | 71<br>72&73 | 1<br>67 | 1967 Total for U.S. of Fuel and Electric Energy Consumption by SIC |
| 8 | 71<br>72&73<br>74-76<br>79-80 | 1<br>62 or 58<br>000<br>01 | 1962 and 1958 Total for U. S. of Fuel and Electric Energy Consumption by SIC (Card 1) |
| 9 | 71<br>72&73<br>74-76<br>79-80 | 1<br>62 or 58<br>000<br>02 | 1962 and 1958 Total for U. S. of Fuel and Electric Energy Consumption by SIC (Card 2) |

## DESCRIPTION OF CARD TYPES (continued)

| Card Type | Identifying Codes Col. | Contains | Data Sets Using This Card Type |
|---|---|---|---|
| 10 | 71 | 1 | 1962 AQCR's Fuel and Electric Energy Consumption by SIC (Card 1) |
| | 72&73 | 62 | |
| | 74-76 | 001 to 100 | |
| | 79-80 | 01 | |
| 11 | 71 | 1 | 1962 AQCR's Fuel and Electric Energy Consumption by SIC (Card 2) |
| | 72&73 | 62 | |
| | 74-76 | 001 to 100 | |
| | 79-80 | 01 | |

## VARIABLE LIST

### General Statistics All Industries Total for AQCR

| Card Type | Field | Description |
|---|---|---|
| 1 | 1 | Number of Total Employees for AQCR (in 1,000) |
| 1 | 2 | All Employees Wages for AQCR (in $100,000) |
| 1 | 3 | Value added by manufacture for AQCR (in $100,000) |
| 1 | 4 | Value of shipment for AQCR (in $100,000) |
| 1 | 5 | New Capital Expenditures for AQCR (in $100,000) |
| 1 | 6-7 | No Data |

### General Statistics for SIC in AQCR

| Card Type | Field | Description |
|---|---|---|
| 2 | 1 | Number of Total Employees for SIC in AQCR (in 1,000) |
| 2 | 2 | All Employees Wages for SIC in AQCR (in $100,000) |
| 2 | 3 | Value added by manufacture for SIC in AQCR (in $100,000) |
| 2 | 4 | Value of shipment for SIC in AQCR (in $100,000) |
| 2 | 5 | New Capital Expenditures for SIC in AQCR (in $100,000 |
| 2 | 6-7 | No Data |

VARIABLE LIST (continued)

## Air Quality Control Costs 1971-1975 (Card 1)

| Card Type | Field | Description |
|---|---|---|
| 3 | 1 | Investment by Industrial Process in AQCR (in $100, 000) |
| 3 | 2 | Annual Cost by Industrial Process in AQCR (in $100, 000) |
| 3 | 3 | Investment by Stationary Combustion in AQCR (in $100, 000) |
| 3 | 4 | Annual Cost by Stationary Combustion in AQCR (in $100, 000) |
| 3 | 5 | Investment by Solid Waste in AQCR (in $100, 000) |
| 3 | 6 | Annual Cost by Solid Waste in AQCR (in $100, 000) |
| 3 | 7 | No Data |

## Air Quality Control Costs 1971-1975 (Card 2)

| Card Type | Field | Description |
|---|---|---|
| 4 | 1 | Total Investment - Lower Limit in AQCR (in $100, 000) |
| 4 | 2 | Total Annual Cost - Lower Limit in AQCR (in $100, 000) |
| 4 | 3 | Total Investment - Expected in AQCR (in $100, 000) |
| 4 | 4 | Total Annual Cost - Expected in AQCR (in $100, 000) |
| 4 | 5 | Total Investment - Upper Limit in AQCR (in $100, 000) |
| 4 | 6 | Total Annual Cost - Upper Limit in AQCR (in $100, 000) |
| 4 | 7 | No Data |

VARIABLE LIST (continued)

## 1967 Unemployment and Work Force Figures for AQCR

| Card Type | Field | Description |
|---|---|---|
| 5 | 1 | Work Force for March 1967 in AQCR (in 100) |
| 5 | 2 | Unemployment Rate in AQCR (in .001) |
| 5 | 3 | 1.0 Percent Sulfur Maximum Fuel Restriction Annual Regional Cost to Steam-Electric Power Generation Combustion Sources: Low for 1974 (in $100,000) |
| 5 | 4-5-6-7 | No Data |

## 1967 AQCR's Local Government Income and Expenditures

| Card Type | Field | Description |
|---|---|---|
| 6 | 1 | Population of AQCR's on July 1, 1968 (in 1,000) |
| 6 | 2 | Per Capita Personal Income 1968 (in dollars) for AQCR |
| 6 | 3 | AQCR Local Government Total 1967 General Revenue (in $1,000,000) |
| 6 | 4 | AQCR Local Government Total 1967 Direct General Expenditures (in $1,000,000) |
| 6 | 5-6-7 | No Data |

VARIABLE LIST (continued)

## Total for U. S. of Fuel and Electric Energy Consumed by SIC's - 1967

| Card Type | Field | Description |
|---|---|---|
| 7 | 1 | Total Cost of Purchased Fuels and Electric Energy by SIC (in $1,000,000) |
| 7 | 2 | Total Cost of Purchased Fuels by SIC's (in $1,000,000) |
| 7 | 3 | Quantity of Electric Energy Purchased by SIC's (million kw/hrs.) |
| 7 | 4 | Cost of Electric Energy Purchased by SIC's (in $1,000,000) |
| 7 | 5-6-7 | No Data |

## Total for U. S. of Fuel and Electric Energy Consumption by SIC's - 1958 and 1962 - Card 1

| Card Type | Field | Description |
|---|---|---|
| 8 | 1 | Total cost of purchased fuels and electric energy by SIC in U. S. ($1,000) |
| 8 | 2 | Total cost of purchased fuels by SIC in U. S. ($1,000) |
| 8 | 3 | Quantity of bituminous coal, lignite and anthracite purchased by SIC in U. S. (1,000 short ton) |
| 8 | 4 | Cost of bituminous coal, lignite and anthracite purchased by SIC in U. S. ($1,000) |
| 8 | 5 | (Only Industry 33) Quantity of coke and breeze purchased by SIC in U. S. (1,000 short ton) |

VARIABLE LIST (continued)

## Total for U. S. of Fuel and Electric Energy Consumption by SIC's - 1958 and 1962 - Card 1 (continued)

| Card Type | Field | Description |
|---|---|---|
| 8 | 6 | (Only Industry 33) Cost of coke and breeze purchased by SIC in U. S. ($1, 000) |
| 8 | 7 | No Data |

## Total for U.S. of Fuel and Electric Energy Consumption by SIC's - 1958 and 1962 - Card 2

| Card Type | Field | Description |
|---|---|---|
| 9 | 1 | Quantity of Fuel Oil (distillate and residual) purchased by SIC in U. S. (1, 000 barrels of 42 gal.) |
| 9 | 2 | Cost of Fuel Oil purchased by SIC in U. S. ($1. 000) |
| 9 | 3 | Quantity of Gas - natural, manufactured, still blast furnace, and coke oven - purchased by SIC in U. S. (million cubic foot) |
| 9 | 4 | Cost of Gas purchased by SIC in U. S. ($1, 000) |
| 9 | 5 | Quantity of Electric Energy purchased by SIC in U. S. (million kw/hrs.) |
| 9 | 6 | Cost of Electric Energy purchased ($1, 000) |
| 9 | 7 | No Data |

VARIABLE LIST (continued)

## 1962 Fuel and Electric Energy Consumption by SIC in AQCR - Card 1

| Card Type | Field | Description |
|---|---|---|
| 10 | 1 | Total cost of purchased fuels and electric energy by SIC in AQCR ($1,000) |
| 10 | 2 | Total cost of purchased fuels by SIC in AQCR ($1,000) |
| 10 | 3 | Quantity of bituminous coal, lignite and anthracite purchased by SIC in AQCR (1,000 short tons) |
| 10 | 4 | Cost of bituminous coal, lignite and anthracite purchased by SIC in AQCR ($1,000) |
| 10 | 5 | (Only Industry 33) Quantity of coke and breeze purchased by SIC in AQCR (1,000 short tons) |
| 10 | 6 | (Only Industry 33) Cost of coke and breeze purchased by SIC in AQCR ($1,000) |
| 10 | 7 | No Data |

## 1962 Fuel and Electric Energy Consumption by SIC in AQCR - Card 2

| Card Type | Field | Description |
|---|---|---|
| 11 | 1 | Quantity of fuel oil (distillate and residual) purchased by SIC in AQCR (1,000 barrels of 42 gal.) |
| 11 | 2 | Cost of fuel oil purchased by SIC in AQCR ($1,000) |
| 11 | 3 | Quantity of gas (natural, manufactured, still blast furnace, and coke oven) (million cubic feet) |
| 11 | 4 | Cost of gas purchased by SIC in AQCR ($1,000) |

VARIABLE LIST (continued)

1962 Fuel and Electric Energy Consumption by SIC in AQCR - Card 2 (continued)

| Card Type | Field | Description |
|---|---|---|
| 11 | 5 | Quantity of electric energy purchased by SIC in AQCR (million kw/hrs.) |
| 11 | 6 | Cost of electric energy purchased by SIC in AQCR |
| 11 | 7 | No Data |

Source: 1963 Census of Manufacturers, Vol. 1, Summary and Subject Statistics, Chapter 7, Fuels and Electric Energy Consumption, Table 6, Total Consumption of Heat and Major Industry Groups Table 10, Consumption According to SMSAs

Card 1

| Column | Contains |
|---|---|
| 1-10 | Total cost of purchased fuels and electric energy ($1,000) |
| 11-20 | Total cost of purchased fuels ($1,000) |
| 21-30 | Quantity of bituminous coal, lignite and anthracite purchased (1,000 short ton) |
| 31-40 | Cost of 11-20 ($1,000) |
| 41-50 | (Only Industry 33) Quantity of coke and breeze purchased (1,000 short ton) |
| 51-60 | (Only Industry 33) Cost of 41-50 ($1,000) |
| 71-80 | Codes<br>72-73 Last two digits of year<br>74-76 AQCR (Air Quality Control Region) Blank for total of all AQCR's<br>77-78 Industry code - SIC<br>79-80 Card number 01 to 02 for this industry |

Card 2

| Column | Contains |
|---|---|
| 1-10 | Quantity of fuel oil (distillate and residual) purchased (1,000 barrels of 42 gal.) |
| 11-20 | Cost of fuel oil ($1,000) |

Card 2 (continued)

| Column | Contains |
|---|---|
| 21-30 | Quantity of gas (natural, manufactured, still blast furnace, and coke oven (million cubic feet) |
| 31-40 | Cost of gas ($1, 000) |
| 41-50 | Quantity electric energy (million kw/hrs. ) purchased |
| 51-60 | Cost of electric energy ($1, 000) |
| 71-80 | Codes<br>Same of card 1 |

*Fuel and Electric Energey Consumed 1962 + 1958 totals for United States According to SIC.

*Fuel and Electric Energy Consumed 1962 for AQCR's by SIC's.

## Base Year Air Quality Control Costs Annual and Investment Costs by Metropolitan Area, Fiscal Years 1971-1975

| Card | Column | Contains |
|---|---|---|
| 1 | 1-10 | Investment by industrial process (in $100, 000) |
| 1 | 11-20 | Annual cost by industrial process (in $100, 000) |
| 1 | 21-30 | Investment by stationary combustion (in $100, 000) |
| 1 | 31-40 | Annual cost by stationary combustion (in $100, 000) |
| 1 | 41-50 | Investment by solid waste (in $100, 000) |
| 1 | 51-60 | Annual cost by solid waste (in $100, 000) |
|  | 72-73 | Year - last two digits |
|  | 74-76 | Air Quality Control Region |
|  | 77-78 | Identifies card as "Air Quality Control Cost" card (contains 40) |
|  | 79-80 | Card numbers 01 or 02 of "Air Quality Control Costs" cards |

| Card | Column | Contains |
|---|---|---|
| 2 | 1-10 | Total investment - lower limit (in $100, 000) |
| 2 | 11-20 | Total annual cost - lower limit ($100, 000) |
| 2 | 21-30 | Total investment - expected (in $100, 000) |
| 2 | 31-40 | Total annual cost - expected (in $100, 000) |
| 2 | 41-50 | Total investment - upper limit (in $100, 000) |
| 2 | 51-60 | Total annual cost - upper limit (in $100, 000) |

## Base Year Air Quality Control Costs
## Annual and Investment Costs by Metropolitan Area, Fiscal Years 1971-1975 (continued)

| Card | Column | Contains |
|---|---|---|
| | 72-73 | Year - last two digits |
| | 74-76 | Air Quality Control Region |
| | 77-78 | Identifies card as "Air Quality Control Cost" card |
| | 79-80 | Card 01 or 02 of "Air Quality Control Cost" cards |

*Air Quality Control Costs 1971-1975 for AQCR's.

Source: Comprehensive Economic Cost Study of Air Pollution Costs for Selected Industries and Selected Regions, prepared for NAPCA, Appendix D.

**Area Trends in Employment and Unemployment**
**June, 1968**
**U. S. Department of Labor**
**Manpower Administration**

**Pages 51-54: Work Force, Unemployment, and Employment in 150 Major Labor Areas**

| **Column** | **Contains** | |
|---|---|---|
| **1-10** | **Work force for March 1967 in hundreds (100)** | |
| **11-20** | **Unemployment rate in tenths of one percent (.001)** | |
| **21-30** | **1974 Low Exhibit V. 17 (1.0% Sulfur Maximum Restriction: Annual Regional Costs to Steam-Electric Power Generation Combustion Sources, Fiscal 1970-1974; Costs and Economic Impacts of Air Pollution Control, Fiscal 1970-1974, Ernst and Ernst)** | |
| **71-80** | **Codes** | |
| | **72-73** | **Last two digits of the year** |
| | **74-76** | **AQCR code** |
| | **77-78** | **Card identification (blank - for these cards)** |
| | **79-80** | **41** |

Source: **1967 Unemployment and Work Force figures.**

Statistical Abstract of the United States
Section 33: Metropolitan Area Statistics
Table 1: SMSA's with 250,000 population or more
Table 2: SMSA's with population below 250,000

AQCR Income and Expenditures for 1967

| Column | Contains | |
|---|---|---|
| 1-10 | Population (1968 July 1) Total (in 1,000) | |
| 11-20 | Personal income, 1968 (per capita total) (in dollars) | |
| 21-30 | Local governments, 1967 (total general revenue) (in million dollars) | |
| 31-40 | Local governments, 1967 (direct general expenditures, total) (in million dollars) | |
| 71-80 | Codes | |
| | 72-72 | Year "67" |
| | 74-76 | AQCR code |
| | 77-78 | Identifies the card 42 |
| | 79-80 | Card no. 1 in all cards |

*AQCR's Income and Expenditures 1967.

1967 Census of Manufacturers
Summary Series - Fuels and Electric Energy Used
All AQCR Total

| Column | Contains | |
|---|---|---|
| 1-10 | Total cost of purchased fuels and electric energy (million dollars - $1,000,000) | |
| 11-20 | Total cost of purchased fuels (million dollars) | |
| 21-30 | Quantity of electric energy purchased (million kw/hrs.) | |
| 31-40 | Cost of electric energy (million dollars) | |
| 41-50 | | |
| 71-80 | Codes | |
| | 72-73 | Last two digits of year |
| | 74-76 | AQCR (Air Quality Control Region)<br>Blank - total for all regions |
| | 77-78 | Industry Code - SIC |
| | 79-80 | Card number within industry (always 01 for this data) |

*Fuel and Electric Energy Consumed, 1967 -- Totals for the United States According to SIC.